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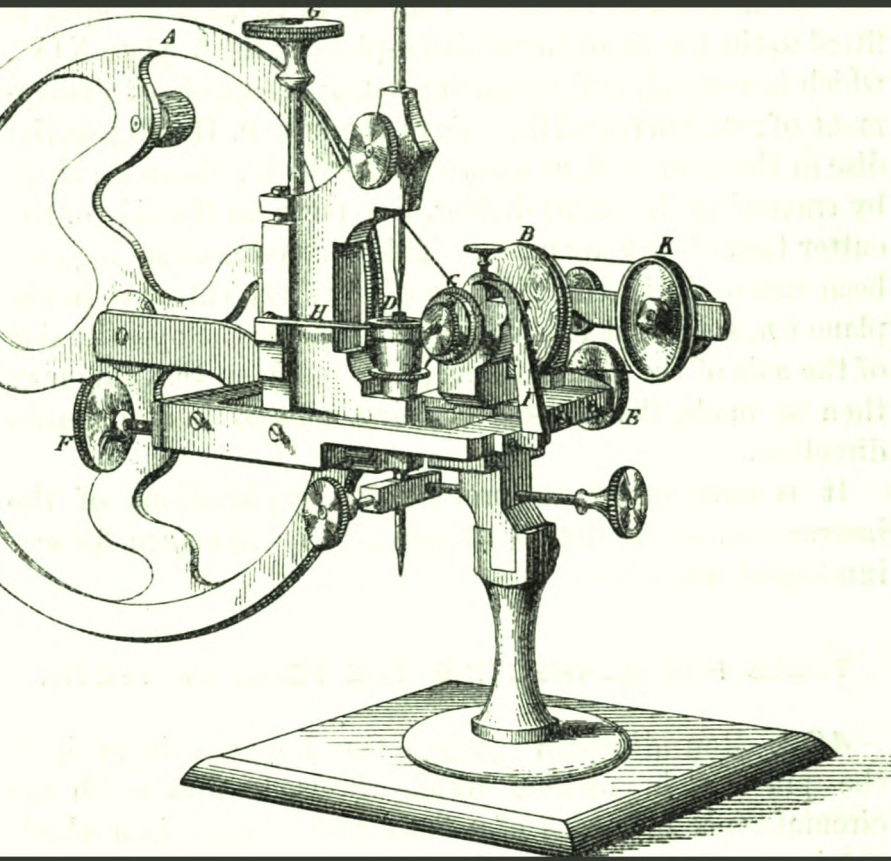

The Watchmaker's Hand-book

Claudius Saunier, Julien John S. Tripplin, Edward Rigg

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THE

WATCHMAKERS' HAND-BOOK.

BY

CLAUDIUS SAUNIER.

INTENDED AS A WORKSHOP COMPANION FOR THOSE WHO ARE ENGAGED IN WATCHMAKING AND THE ALLIED MECHANICAL ARTS.

ENGLISH EDITION.

TRANSLATED, REVISED, AND CONSIDERABLY AUGMENTED

BY

JULIEN TRIPPLIN,

Besançon Watch Manufacturer,

AND

EDWARD RIGG, M.A.,

Assayer in the Royal Mint.

Illustrated by numerous Wood-blocks and Copper Plates.

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PREFACE.

THE present Handbook is issued in fulfilment of a promise made in the preface to the *Treatise on Modern Horology*, and but little explanation is needed as to the general scope of the work.

A glance at the Table of Contents will show that the information given is essentially practical in its character, and such as will be of use to the watchmaker in his daily work. The volume is thus in no sense an abridgment of the *Treatise on Modern Horology*, but may rather be considered as a companion to that work, neither being complete without the other.

M. Saunier's writings occupy a unique position on the Continent as works of reference for all who are engaged in watchmaking, and it may not be out of place to observe that the English Edition of his Treatise, which we completed in the early part of the year 1880, promises to take a similar place among English-speaking communities; it has already been awarded a Diploma of Merit at Melbourne

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(1880), and a Gold Medal at Paris (1881), on account of "services rendered to the cause of Horology."

In recent years the work of the ordinary watch-jobber and repairer has undergone considerable change. The apprenticeship he serves, if indeed it can be called a real apprenticeship, is shorter than formerly. The immense number of badly constructed watches that he is called upon to put in going order for a trifling remuneration, compels him to replace the older methods of procedure by others, whenever by so doing time can be saved. From his point of view, then, the value of the present Hand-book can hardly be over-estimated, since it contains, in a readily accessible form, many details as to the working of metals, and descriptions of various practical operations, new and improved forms of tools, &c., never before published in this country.

But the volume will be found of daily use to a wider circle of workers than those above referred to. We believe that there is hardly a branch of the watchmaking trade which may not benefit by the numerous practical details that are given; indeed, although the work is specially designed for the use of watchmakers, a great portion of it will be seen to be no less applicable to other mechanical arts.

M. Saunier's original works, the *Guide-Manuel de l'Horloger*, and the *Recueil des Procédés pratiques*, which

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appeared as separate volumes, have been incorporated in this English Edition, a large amount of additional information being at the same time added. As the second contained many details that more properly belonged to the first, and *vice versâ*, it has been thought desirable to remodel the whole, and, as will be seen from the Table of Contents, the six parts that constitute the work are distinct in their character. The slight inconvenience thus caused owing to irregularity in the references to the engravings will, it is hoped, be neutralized by the Key to the Plates (pp. 481—2), by means of which the letterpress relating to each figure can be at once found.

With a view to further facilitate the use of this Handbook as a work of daily reference, an unusually full index has been added, which the reader is recommended in all cases to consult, and no effort has been spared to make the cross references in the body of the work as complete as possible.

It seems desirable here to give some explanation in regard to several of the practical methods described. Every watchmaker will at once recognize that receipts are included which are of the nature of makeshifts, and that it would in many cases be better to replace a piece by a new one rather than to repair it in the manner indicated. But on the other hand it has been felt that the work will often be appealed to by those who, from various circumstances, may be prevented from making or procuring a new part

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that will suit the watch under repair, while those who are not so situated will have no difficulty in deciding for themselves as to which method to adopt.

We would express our thanks to various friends to whom we are indebted for assistance in the preparation of the work, and we trust that the present edition may be found as useful in this country as the original has proved itself on the Continent.

JULIEN TRIPPLIN.

EDWARD RIGG.

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THE

WATCHMAKERS' HAND-BOOK.

PART I.

ARITHMETIC, GEOMETRY & MEASUREMENT.

ARITHMETIC.

1. At the present day it is absolutely necessary that the watchmaker be acquainted with the rules of arithmetic, and that he have some knowledge of geometry. He will have to perform a calculation when altering a depth or ascertaining the numbers of teeth in a train of whatever horological mechanism he is making or repairing, as well as in numerous other cases.

A knowledge of geometry will enable him to ascertain the dimensions of solid bodies, and he will be in a position to apply the rules that form the basis of linear drawing; every watchmaker worthy of the name should be able to make and to understand the drawing of a machine or of any horological instrument.

Many inventors, and even ordinary workmen, would avoid a large amount of handwork, often useless and occupying much time, if, instead of at once putting an idea

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into practice with brass and steel, they were able, as a preliminary, to make for themselves a correct design drawn to scale.

2. We must assume the reader to be familiar with the four first rules of arithmetic as far as regards whole numbers and proper fractions; moreover they can be studied in a great number of special text-books.

Besides possessing a knowledge of *prime* numbers, numbers that is which have no divisors but unity and themselves, the watchmaker should be able to determine the greatest common measure of several numbers, a rule which is of the first importance in calculating a train of wheels that is at all complicated.

We shall confine our attention to the methods of extracting square roots and proportions, the rules for which may have been forgotten owing to their being less frequently employed than the more common rules of arithmetic; they are of frequent use in horology.

EXPLANATION OF CERTAIN SIGNS EMPLOYED IN CALCULATIONS.

3. The sign + means *plus* or "added to." The sign × (which must be carefully distinguished from the last) means "multiplied by," and ÷ stands for "divided by." *Minus* (—) means "diminished by," and the sign = indicates that the terms on each side are of equal value.

Thus the expression—

$$20 + 15 \times 10 + 12 \div 3 = 190 - 16$$

would be read thus :—

20 *plus* 15 *multiplied by* 10 *plus* 12 *divided by* 3 *is equal to* 190 *minus* 16.

Division is more usually indicated by a line between the

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two figures placed with the divisor below the dividend: thus $\frac{10}{3}$ is expressed as 10 *divided by* 3, or *ten-thirds*.

The signs of proportion are two superposed dots (thus :) read "*is to*," and four dots (thus ::) to express "*as*."

POWERS AND ROOTS.

4. A power of a number is the product obtained by multiplying that number a certain number of times by itself.

$5 \times 5 = 25$. 25 is the *second power* or square of 5.

$6 \times 6 \times 6 = 216$. 216 is 6 raised to a *third power* or cubed.

It is usual to indicate that a number must be raised to a definite power by inserting a corresponding small number at the right-hand top corner. Thus :—

$$7^3 = 7 \times 7 \times 7.$$

A *root* of a number is that quantity which, when multiplied by itself a definite number of times, will produce the initial number. Thus, in the above examples, 5 is the *square root* of 25; and 6 is the *cube root* of 216.

In order to indicate that a root must be extracted, the number is placed under the sign $\surd$, termed the *radix*, and the index of the root is expressed by a little figure placed outside the bend.

$$\sqrt[2]{25} = 5 \text{ and } \sqrt[3]{216} = 6.$$

It is usual to omit the index number for square roots, so that the radix without any index number means that the square root is to be taken.

5. To extract the square root of a whole number.*—

* The rule is adapted from Barnard Smith's School Arithmetic (Macmillan).

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Place a point or dot over the units' place of the given number, and thence over every second figure to the left of that place, thus dividing the whole number into several periods. The number of points will show the number of figures in the required root.

Find the greatest number whose square is contained in the first period at the left; this is the first figure in the root, and may be ascertained by the aid of the following table :—

Number	1,	4,	9,	16,	25,	36,	49,	64,	81
Square root	1,	2,	3,	4,	5,	6,	7,	8,	9

Subtract the square of the number so determined from the first period, and to the remainder bring down the second period. Divide the number thus formed, omitting the last figure, by twice the part of the root already obtained, and annex the quotient to the root and also to the divisor. Then multiply the divisor, as it now stands, by the part of the root last obtained, and subtract the product from the number formed, as above mentioned, by the first remainder and second period. If there be more periods to be brought down the operation must be repeated, and if, when all the periods have been so brought down, there is a remainder, the given number has no exact square root.

6. If the number be a *decimal fraction* or a whole number and decimal combined, proceed in a similar manner, but observe that a point must *always* occur over the units' figure and on alternate figures from it on either side to the right and left. A decimal point will be placed in the square root immediately before bringing down the first decimal period, and, in cases where the given number has no exact root, it may be approximated to by bringing down successive pairs of cyphers.

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7. *Example.*—Extract the square root of 273,529.

```
          . . .
          273529 (523
          25
          ----
102     | 235
        | 204
        | ----
1043    |  3129
        |  3129
        | -----
```

Applying the above rule, the square of 5 or 25, the largest contained in 27, is subtracted from the first period, and to the remainder the second period, 35 is attached. The divisor for the dividend so formed is obtained by doubling the portion of the root already determined (5), and annexing 2 to the 10 since 10 will divide twice into 23, the dividend with the last figure omitted. The 2 is also added to the quotient as forming a figure in the root, and 102 multiplied by it as in ordinary division. The next period, 29, having been brought down to the remainder thus obtained, a similar operation is again gone through, the entire quotient, so far as it has been determined, being each time doubled.

PROPORTION.

8. When we compare two numbers with a view to ascertain how much one is smaller or larger than another, we obtain a ratio of difference :—

$$6 - 2 = 4$$

such a ratio is termed an *arithmetical ratio.*

9. When the difference between two numbers is ascertained by seeing how many times one is contained in the other, we obtain a *geometrical ratio;* this, then, is always obtained by division.

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A *proportion* is defined as the equality of two ratios. Thus:

$\frac{30}{6} = 5$ and $\frac{40}{8} = 5$, and we may therefore state that—

$$\frac{30}{6} = \frac{40}{8}$$

or, as it is usually written (3),

$$30 : 6 :: 40 : 8$$

constitutes a geometrical proportion.

The first and fourth terms of a proportion are known as the *extremes*. The second and third are the *means*.

Fundamental rule.—In every proportion the product of the extremes is equal to the product of the means.

Thus: $30 \times 8 = 6 \times 40 = 240$

Hence it follows that if we only know three terms we can always determine the fourth, the *unknown*, which is usually represented by the letter x.

Take the proportion $12 : 3 :: 16 : x$.

$3 \times 16 = 48$ (the product of the means); this product divided by 12 (the known extreme) gives 4 as the value of x.

If the two extremes are given and one mean, we must then take the product of the extremes and divide by the known mean.

Thus in the proportion:—

$$20 : 5 :: x : 25$$

we have:—

$$20 \times 25 = 500. \quad x = \frac{500}{5} = 100.$$

Similar powers or roots of four numbers that are in proportion will also be in proportion.

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If the four terms be multiplied or divided by the same number, the resulting numbers will still be in proportion.

ELEMENTS OF PRACTICAL GEOMETRY.

10. The object of geometry is to measure the extent of bodies.

A body has three dimensions: *length*, *breadth*, and *thickness*, and one of these latter is sometimes termed *height* or *depth*.

Either dimension taken by itself is measured by a straight *line*.

When the extent of a body is expressed by combining any two dimensions, it is termed *area* or *surface*, and when three are employed we obtain the solid measure or *volume*.

Plane geometry only takes cognizance of figures situated in one plane or surface, and therefore only possessing two dimensions; *solid* geometry regards bodies as having all three dimensions.

Two lines are *parallel* when their distance apart is at all points the same. A similar definition is applicable to parallel planes.

Two lines or planes meeting each other will form an *angle*. The point at which they meet or intersect is termed the *apex* or *summit* of the angle.

A straight line is *perpendicular* or *at right angles* to another straight line, or to a plane, when all the angles which it makes with that line or plane are equal.

A *circumference* of a circle is a curved line *l c d f* (fig. 1, plate I.), such that all its points are equally distant from an internal point, *o*, termed the *centre*. The *circle* is the space enclosed by the circumference.

It will be noticed that in geometry these two words are distinguished, although they are frequently referred to as identical. Thus, the rim of a wheel or balance is generally termed a circle.

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Two circles (*l c d f* and *b r a*, fig. 1, plate I.) described from the same centre are said to be *concentric*. When their centres do not coincide they are called *excentric* with regard to one another.

Any portion of a circumference, such as *f n d* (same figure), is termed an *arc* of the circumference, or, more commonly, an *arc of a circle*.

A *chord* is a straight line, *f d*, which unites the two extremities of an arc.

When the chord passes through the centre of a circle it is termed a *diameter*.

The *radius* of a circle or circumference is a straight line drawn from the centre to the circumference; and all the radii that can be thus drawn are equal. A diameter is, then, always double the radius, and, conversely, the radius is always half the diameter.

A *tangent* is a straight line that only touches a circumference at one point, as *g l* (fig. 1, plate I.); whereas a *secant* cuts the circle, as *i j*.

A circumference is assumed to be divided into 360 equal parts, termed *degrees*. The degree is subdivided into 60 equal parts, or *minutes*, and the minute into 60 *seconds*. These are respectively symbolized by the marks ° ′ ″ placed at the top right-hand corner of the figure.

Such an expression as 18° 30′ 15·5″ would, then, be read —18 *degrees*, 30 *minutes*, and 15·5 *seconds*.

11. Ratio of the circumference to the diameter.— The diameter of a circle is to the circumference as 7 : 22; or, employing decimal fractions, as 1 : 3·14159 (a number which, in algebra, is always represented by the Greek letter π).

Knowing a diameter (D), the circumference, x, can be ascertained from the proportion :—

$$1 : 3{\cdot}14159 :: D : x.$$

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Knowing a circumference (c), the diameter, x, can be determined from the proportion :—

$$3{\cdot}14159 : 1 :: c : x.$$

The latter proportion will also give the value of the radius, which is half a diameter.

12. The *superficial area of a circle* is equal to the circumference multiplied by half the radius, or to the square of the radius multiplied by 3·14159.

A sector is the surface enclosed between an arc and two radii bounding it, as *b* o *r k* (fig. 1, plate I.).

The area or surface of a sector can be ascertained by multiplying the length of the arc by half the radius.

A *segment* of a circle is the portion intercepted between an arc and its chord, as *f d n* (fig. 1, plate I.).

The surface of a segment, as *b k r s*, can be obtained by subtracting from the area of the sector o *b k r*, the area of the triangle, *b r* o (**15**).

13. *Ring.*—To determine the surface of a flat ring, the area of the inner circle must be subtracted from that of the outer circle ; in other words, take the difference between the areas of the two circles that fix the inner and outer diameters of the ring.

The area of a flat ring can also be calculated by adding together the internal and external diameters ; then multiply the number so obtained by their difference and by the decimal fraction 0·7854 (that is, $\frac{3{\cdot}14159}{4}$). The product will be the required area.

14. *Angles and their measurement.*—When two lines meet one another, they form an angle, as we have already seen. If we take the apex as the centre of a circle, the number of degrees intercepted between the two straight lines gives a measure of this angle.

The angle measured by a quarter of a circumference, or 90°, is termed a *right angle.*

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An *obtuse* angle is greater than a right angle, and an angle that is less is termed an *acute* angle.

15. Triangles, squares, &c., and their measurement. —The triangle or plane area enclosed within three straight lines joined two and two together (A, B, C, fig. 2, plate I.) is said to be *rectangular* when one of its angles is a right angle ; it is *equilateral* when the three sides are equal, under which circumstances the three angles are also equal ; and *isosceles* when only two sides are of equal length.

The sum of the three angles of a triangle is always equal to two right angles. If only two of the angles are known, it is thus easy to determine the third.

Similar triangles are characterized by the fact that their homologous sides (that is, the sides opposite to equal angles) are proportional.

Peculiarity of the right-angled triangle.—The square described on the longest side, termed the *hypothenuse* (B, fig. 2, plate I.), is equal to the sum of the squares described on the two other sides. Hence it follows that, if the lengths of the two shorter sides are known, that of the hypothenuse can be ascertained by extracting the square root of the number formed by adding together the squares formed on these two sides (**5-7**).

If the hypothenuse is known and one of the shorter sides, the third can be determined by extracting the square root of the number formed by subtracting the square of the known side from the square of the hypothenuse.

The *surface of a triangle* is determined by multiplying one of the sides by half the perpendicular height of the angle opposite to this side.

16. The *surface of a square* or of an oblong or *rectangle* (*a b c d*, fig. 3, plate I.), is equal to the product of the base multiplied by the height.

The sum of the squares described on the four sides is equal to twice the square described on a diagonal. This diagonal divides the rectangle into two equal rectangular triangles.

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17. The *surface of a parallelogram or lozenge*, a plane figure with four sides, opposite pairs of which are parallel (*c f g d* and *c i j d*, fig. 3, plate I.), is equal to the product of one side multiplied by the perpendicular height of the figure.

The sum of the squares described on the four sides of a parallelogram is equal to the sum of the squares described on the two diagonals.

18. Measure of various solid bodies.—The volume of a cube or parallelopiped (that is, a body bounded by six four-sided figures, every opposite two of which are parallel) is obtained by multiplying the surface of the base by the height.

The *volume* of a straight cylinder is the product of the surface of the circle which forms its base into the height of the cylinder.

The *area* of the curved surface of a cylinder is obtained by multiplying the circumference of the circle forming its base by the height.

The *volume* of a tube or cylindrical ring of rectangular section, such as the arbor-nut of a barrel, or the rim of a circular balance, &c., is equal to the product of the plane surface of its base (**13**) into its height.

The *volume* of a *right cone* or of a *regular pyramid* is the product of the base into a third of the height.

The *surface* of a *sphere* may be determined by multiplying the square of the diameter by 3·1416 (**11**).

The *volume* of a sphere is equal to this surface multiplied by a third of the radius.

GEOMETRICAL DRAWING.

19. An elementary knowledge of the art of drawing, an ability to represent the outlines of objects by simple lines, is of the first importance to the watchmaker.

Such a design is obtained by projecting on to one plane all the visible points of the object represented.

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Projection on a vertical plane gives an *elevation;* the object is looked at from one side.

Projection on to a horizontal plane produces a *plan;* the object is observed from above, thus giving a bird's-eye view.

The projection of a point on a vertical or horizontal plane is the foot of the perpendicular, from the given point on to the plane.

Assume the line *n m* (fig. 4, plate I.), to be fixed in space; its horizontal projection will give *c d*, and its vertical projection, *r s*.

Miscellaneous details.—When one portion of the object to be represented is found to pass behind other pieces so that it cannot be seen, the continuation is frequently indicated by dotted lines.

Surfaces that are situated in planes one behind the other are shaded, the more deeply according as they are farther back. This shading is produced by a number of parallel lines which may be vertical or horizontal.

Parts that are in relief are indicated by projected shadows, or by increasing the thickness of a line that would cast a shadow.

In order to distinguish the several shadings or to emphasize the lines by which they are separated, it is a very usual, though not invariable, practice, to assume the light to be coming from the left, falling on the picture from over the shoulder of the draughtsman at an inclination of about 45°.

When drawing a square in relief, such as *a b c d* (fig. 3, plate I.), if it is an elevation, the lines *c d*, *b d* will be made darkest; but if it is a plan, the lines *a b*, *d b* should be brought into prominence.

These several directions will be found useful when a hole, any cavity, a pin, a round object, &c., has to be depicted. As a general rule, the thick lines should indicate the position at which a shadow would form, the light being assumed to fall on the drawing in the manner indicated above.

A *section* shows a body as it would appear if cut in two,

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and one portion removed in order to expose the interior. A section is indicated by a series of parallel lines drawn close together and at an inclination of about 45° to the vertical.

In order to leave more room for important details, or to show objects that are situated behind, a piece is often broken off by an irregular line.

Lines formed by a series of detached points sometimes serve as a means of associating several figures representing the same object looked at in different directions.

20. Tracing and transfering.—These two operations are resorted to when it is required to obtain one or more copies of a picture or design already drawn.

Tracing consists in laying a piece of tissue or other translucent paper over the drawing and copying it by following over the lines that are visible with a pencil. Or ordinary paper can be used for the purpose, providing it is not too thick, if the picture be placed against the pane of a window or, what is more convenient, on a sheet of glass used as a desk and illuminated from below. When either sheet of paper is too thick to allow sufficient light to pass one or other of the methods of transfering indicated below must be resorted to.

21. This operation consists in reproducing a tracing on a separate sheet of paper or on metal that is to be engraved. Either of the following methods may be adopted :—

(1.) The picture to be transferred is fixed to a table if tracing paper is to be used, or to a sheet of glass if only ordinary paper is available. The lines are then traced with a black lead pencil that must not be too hard. When this is finished it is laid, face downwards, on a sheet of white paper, taking care that both sheets are so fixed that they shall not slip. Apply pressure to the upper surface by tapping with a small pad made on purpose and, at the same time, gently rubbing. Experience will very soon show how hard the pad should be. Now remove the tracing, still taking care to avoid any

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slipping, and a faint reproduction of the design will be found on the lower sheet of paper. It is only necessary to follow over the lines with Indian ink. The figure will be reversed, but a transfer with it in the original direction may be obtained by inverting the picture and laying it on glass so as to make a reverse tracing.

(2.) Lay the picture on a desk and trace it with ink on a very transparent sheet of paper. When the ink is dry, invert the tracing and blacken the back with a crayon that is not too hard. Now lay the tracing, with the ink side uppermost, on a sheet of clean paper, taking care to avoid slipping, and go over the several lines with an agate or metal style, avoiding excessive pressure on account of the risk of tearing the paper. On removing the upper sheet an impression will be found not reversed. Go over all the lines with Indian ink and clean the paper with India-rubber or bread crumbs.

Observations.—The choice of paper and pencil is not a matter of indifference. All kinds of paper do not receive an impression equally well, neither do all pencils or crayons transfer with equal facility. The black Conté crayon, No. 2, will generally be found best suited to such work.

22. To transfer an engraved design.—This method is available when it is desired to obtain an impression, for example, of the engraved surface of a watch case.

Procure some of the ink used by copper-plate engravers, or, in its absence, ordinary stencil ink may be used. Taking a small quantity on the end of the finger, tap it on the surface of a glass plate, in order that the ink may be distributed, leaving only a small quantity evenly spread over the finger: tap with the finger thus prepared over the watch case long enough to make sure that all the surface in relief has received some ink; take a piece of writing paper and, after slightly moistening it, spread it over this surface. Lay above this a piece of paper folded in four and pass over it in all directions any round body, such as a small tool handle,

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and with some pressure; then raise the papers without allowing them to slide.

If the operation has been carefully performed a very clear impression will thus be obtained of the engraved surface. The relief will be black and the hollows white, but, of course, the figure is reversed like that in a looking-glass. If required in the right direction it must be traced through to the other side of the paper.

DRAWING INSTRUMENTS.

23. It is needless here to describe the rule, set-square, T-square, bow-compass, &c., as every one knows them.

To verify the accuracy of a rule.—On a perfectly flat smooth surface carefully draw, with the rule in question, a fine straight line. Then turn the rule over, hinging it as it were on the line just drawn; if quite straight the edge of the rule will exactly coincide with the line, in this new position, throughout its entire length. Each edge should be thus examined.

To verify the accuracy of a set-square.—Having fixed an accurate rule on a smooth surface, place one edge of the set-square against it, and draw a line along the edge perpendicular to the rule; then, having turned the set-square, hinging it on the line just drawn, bring it against the rule and along the line. If the square is true the edge and line will coincide throughout their length.

24. The protractor.—Fig. 6, plate I., represents a common form of this instrument. It is made of horn, or, if of metal, the inner portion is cut away, leaving only a base and a semicircular arc, which is divided into 180 equal parts or degrees; a complete circle would therefore consist of 360 such degrees. The point D, indicating the centre of the arc, should be very small in order to facilitate the exact setting of it at the apex of an angle.

When an angle has to be drawn with accuracy, the pro-

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tractor is unsuitable ; it will be better to adopt one of the methods described at paragraph **37** (Consult also *Treatise*, p. 442), or trigonometrical methods.

25. Drawing scales.—When an object is represented by a drawing, if the dimensions are the same as those of the object itself, or, rather, as they would project on to a horizontal or vertical plane, the drawing is said to be full size ; but the object is generally represented either on an increased or diminished scale, which is defined, the proportion between all the parts being still, however, maintained the same.

With a view to avoid the many calculations that such a change would involve, it is usual to employ drawing scales. The following notes will sufficiently explain their construction and use.

Let it be required to reproduce a large drawing on a small scale, in such a proportion that the dimensions are reduced in the ratio of 10 to 1.

Take a straight line of indefinite length, *a b*, fig. 7, plate I., and mark out on it spaces equal to *a* 1, which represents any measurement taken on the original object; at *c*, the 10th division, draw a perpendicular, and on it measure *c g* equal to *a* 1, or one-tenth of *a c* and join *a g*.

Through the points indicating the divisions into tenths draw lines parallel to *c g*, and you will thus have a series of triangles, *d a* 1, *d' a* 2, *d'' a* 3, &c., similar to the triangle *g a c*. In virtue of a well-known property of such triangles (**15**), *d* 1 will be one-tenth of *a* 1 ; *d'* 2 one-tenth of *a* 2 ; and so on.

Thus, if a measurement taken on the object, or on a large drawing, is equal to *a x*, it will only be needful to turn the compass on the point *x* as a centre, and to observe accurately the perpendicular height, *x z*, to ascertain the corresponding measurement on the reduced scale.

Such a scale can be employed to measure metres and

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decimetres, or feet and inches (but, in this latter case, it would have been necessary to mark off 12 instead of 10 divisions from *a*). Since *a* 1 might be made to represent one metre ; *a* 2, two metres, &c.; in virtue of the principle of the triangle already referred to, *d* 1 will be the tenth of *a* 1, and will therefore represent a decimetre ; *d'* 2 will represent two decimetres, &c. The length required to represent, say, 5·3 metres will be ascertained by taking the distance *a* 5, to which the distance *d''* 3 is added. Similarly 6 feet 2 inches would be given by *a* 6, to which *d'* 2 is added on a 12-division scale.

26. The following description of one of these decimal scales, which is engraved on metal or ivory, and often included in cases of drawing instruments, will suffice to enable anyone to construct a scale on this principle, that goes to a still further degree of accuracy, measuring, for example, metres, decimetres, and millimetres, or yards, feet, and inches.

Let A B, fig. 8, plate I., be a flat rectangular rule, divided throughout its length by parallel equidistant lines, into ten strips. At right angles to these are the lines *o o'*, *a a'*, &c., separated from one another by a distance of one centimetre (doubled in the drawing in order to make the details more clear). The first centimetre is subdivided along the two edges, A *o*, *n o'*, into 10 equal parts or millimetres, and the division, *o*, on the upper edge is joined by an oblique line with the 1 on the lower edge, and the others by parallel oblique lines as shown in the figure. Thus *c i* will be one-tenth of a millimetre, *s j* two-tenths, and so on.

If the compass is opened so as to reach from *x* to *z*, it will be seen that it covers a space of 16 millimetres and 2-10ths of a millimetre, for there are 1 large division (or 10 mm.), 6 smaller divisions (or millimetres) plus a fraction of a millimetre equal to *s j* or 2-10ths of a millimetre.

27. Sector.—When it is required to reduce the scale of a drawing, subject to the condition that the dimensions shall

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be all diminished in the ratio of two given lines, we may state the problem thus :—

The longer of the two given lines is to the shorter, as any given dimensions of the old drawing is to x. The value of x thus determined will be the corresponding dimension of the new figure.

Such a rule of three proposition would involve a considerable amount of work, and the required result can be arrived at with greater facility by the geometrical method which forms the basis of the scale just described, or, better still, by using the sector shown in fig. 9, plate I. It consists of two brass or ivory legs hinged about a centre m which is at the apex of the angle $n\ m\ c$ formed by two straight lines similarly divided into equal parts.

It is employed as follows :—Let us assume that a drawing has to be reduced in the ratio of the line A to the line B ; set off the length A along $m\ n$ and suppose its extremity to be at s, where division number 5 occurs. Open a compass to a distance equal to B, and placing one point at s, open the two legs of the scale until the second point coincides exactly with the corresponding division t, that is, with the 5 on the other leg, $m\ c$. Maintaining the scale open to this amount, it is only needful, after measuring a distance on the original drawing or object, to set it off along $m\ n$, and to measure the distance between its extremity and the corresponding point on the other leg ; this distance will be the dimension on the reduced scale.

28. Proportional compass.—This consists of two equal stems terminating with points, fig. 10, plate I. They are cut through for a portion of their length, and provided with a slide forming a hinge, that can be clamped by a screw a in any position. Graduations on the two slots and a mark on the slide indicate in what position of the slide a, the length $a\ b$ (equal to $a\ g$) is equal to $\frac{1}{2}$, $\frac{1}{3}$, $\frac{1}{4}$, $\frac{1}{5}$, &c., of $a\ d$; and thus show what is the ratio of $g\ b$ to $c\ d$, a ratio which is independent of the extent to which the arms are opened.

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29. The vernier.—The vernier consists of a small graduated slide which is adapted to a graduated rule or circular arc with a view to ascertain the value of small fractional parts of the divisions marked on the rule or arc.

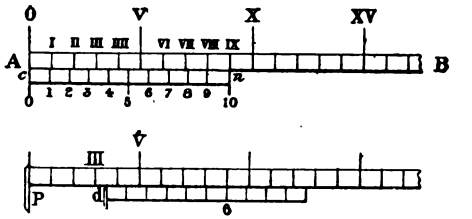

FIG. I.

Let A B, in the above figure, be a rule divided into millimetres (the proportions are enlarged in the drawing so as to avoid confusion among the lines), and let it be required to determine a length to within the tenth of a millimetre.

As the measurement is required to the tenth, take ten less one or nine of the divisions of the scale ; they will extend from 0 to IX, and this represents the acting length of the vernier.

Subdivide the vernier into ten equal parts ; it is manifest that each graduation of the vernier differs from the original subdivisions of the rule by 1-10th of a graduation of the latter. In other words, unity on the vernier is equal to 9-10ths of unity on the rule.

When the rule and vernier are placed as shown in the upper figure, so that the 0 on both scales coincide, the successive divisions on the rule (marked with Roman numerals for distinction) will be progressively more and more in advance of the corresponding divisions on the vernier in the following proportion :—

The marks I and 1 are 1-10th apart ; the marks II and 2, 2-10ths ; III and 3, 3-10ths ; and so on, the mark X being 10-10ths, or one complete division in advance of 10, this division being a unit on the scale.

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Thus if the vernier is caused to slide along the edge of the rule, when 1 coincides with I the vernier has advanced 1-10th ; when 2 coincides with II, it has advanced 2-10ths ; and so on.

Let it be required to determine the distance P *d*. The division 6 on the vernier coincides with a division of the scale ; hence it follows that the extremity *d* of the vernier is at a distance of 6-10ths millimetre from III, the next division of the scale to the left. The distance between P and *d* is thus 3·6 millimetres.

With a vernier showing tenths if two consecutive divisions of the vernier fall between two divisions on the rule, and there does not appear to be a tendency towards one side more than towards another, even when observed with a strong glass, it is possible to take an approximate reading to the twentieth.

In measuring circular arcs a curved vernier is used in place of a straight one, and its graduations are made to correspond with those on the circle as shown in fig. 5, plate I.

30. Micrometer screw.—By employing a micrometer screw it is possible to measure infinitesimal amounts, but the screw must be perfectly accurate, and must work without appreciable backlash, or loss of time.

Assume V, fig. 11, plate I., to be such a screw, having a pitch of 1 millimetre. It will advance by this amount with each complete rotation.

To the head of the screw is attached a disc of such a size that its rim can be divided into a number of equal parts, say a hundred. These graduations may be marks on the edge or notches cut in it when an index is required to stop in them ; but the index is less frequently met with than a simple divided straight-edge almost in contact with the disc. The divisions round the disc are numbered in ascending order as the points *c* and *a* separate, so that zero comes under the index or rule when these points are in contact.

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Readings of the numbers will thus afford a measure of the displacement of the point of the screw.

When the disc is rotated the point *a* will move towards or from *c* by 1-100th of a millimetre for each division passing under the straight-edge, and one millimetre for each complete rotation. It is thus possible to ascertain the dimensions of an object when it enters without play between the two jaws to within an error of about 1-100th of a millimetre if the instrument is accurately made.

If, instead of passing the object between the two jaws, it is gripped by them, the measurement will be less exact, as no account is taken of the pressure exerted and of the elasticity. (**44.** See also art. 1487 in the *Treatise*.)

Many of the small instruments that are employed by watchmakers for measuring moderate thicknesses give erroneous indications. We have explained in the *Treatise on Modern Horology* (articles 1484—8) the mode in which they should be made, in order to increase their accuracy.*

GEOMETRICAL DRAWINGS.

31. Sketches.—It is advisable from an early age to accustom oneself to make rapid freehand sketches of objects as they present themselves to the eye. Such a sketch will help in the preparation of a more exact drawing, which involves a knowledge of the several geometrical methods given below.

A drawing may be transferred, reduced or enlarged as follows :—

Draw across the original picture a number of equidistant vertical and horizontal lines, forming perfect squares, and number the two sets of line in succession. Then draw a similar series of lines on a clean sheet of paper, setting the

* The reader who is desirous of obtaining further information on this important subject may consult a valuable Report published in 1877, at Geneva, by Prof. Thury, "Sur la construction d'un nouvel outil pour la mesure des épaisseurs."

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lines at an equal, less or greater distance apart, and copy in succession the parts of the figure that are enclosed within the several squares.

As it is not always possible to draw lines across a figure, they may be replaced by a frame carrying fine wires stretched in the two directions. The frame is laid over the original drawing, which can then be copied, as above explained, on a sheet of paper divided into squares (fig. 20, plate I.).

This frame may, moreover, afford assistance in the drawing of solid objects. Having placed it above or in front of the object and in contact with it, copy on to the sectional paper the contents of each corresponding square, taking care to look at the object perpendicularly. With a little practice and by placing the eye in the correct position and always at the same distance from the frame (a distance which may be regulated by a glass), a sketch in fair proportion may easily be obtained.

32. To erect a perpendicular on a straight line.—Either the compass or a set-square can be employed; the use of this latter instrument is so simple that no further reference need be made to it. Assume *a*, fig. 14, plate I., to be the point in the line *n m* at which a perpendicular is to be drawn. On either side of *a* measure off equal distances *a n*, *a m*: from *n* and *m*, with a radius about equal to the distance *n m*, draw two circular arcs cutting one another. If their point of intersection *b* be joined to *a*, the line *a b* will be the required perpendicular.

33. To erect a perpendicular at the extremity of a line.—From the extremity *c*, fig. 15, mark off four equal parts towards *s*. From *s*, with a radius equal to five such parts, describe a circular arc, and from *c*, with a radius of three such parts, describe another arc cutting the first at *d*. The line joining *c* and *d* will be perpendicular to *s c*.

For the square of 5 is 25, and this is equal to the square of 4 or 16 plus the square of 3 or 9. Thus the triangle *s c d* must be right-angled (**15**).

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Or the following method may be adopted:—With any centre *i* and radius *i g* (fig. 16), as large as possible, describe a circumference passing through *g*. From the point *p*, where the circle cuts the line, draw the diameter *p i h*. If the point *h* be joined to *g*, it is the required perpendicular; for, by a property of the semicircle, the angle *h g p* is a right angle.

34. To let fall a perpendicular on a straight line.—In order to let fall a perpendicular from the point *a* on to the line *b c* (fig. 17, plate I.), describe from *a* as a centre, a circular arc sufficiently large, cutting the straight line in two points, *b* and *c*. From these two points, with the same opening of the compass, draw on the under side of the line two arcs that intersect. The point of intersection *o* joined to *a* gives the required perpendicular.

35. To draw parallel straight lines.—Having fixed a good straight edge over the drawing, as many parallel lines as are required may be drawn with the aid of a set-square which is caused to slide along the rule. They will be vertical, horizontal or inclined, according to the position of the rule, which must be set exactly perpendicular to the direction in which the parallel lines are to be drawn (fig. 18, plate I.).

To draw, from a given point, a line parallel to a given line.—Let *d* be the given point, and *a b* the given line (fig. 19, plate I.). From *d* draw the circular arc *a c*, and from *a* where it cuts *a b*, with the same radius describe the arc *d b*. From *a* set off on *a c*, a distance equal to *d b*. The line joining *d* and *c* is the required parallel.

36. To subdivide a line into equal parts.—Let it be required to divide the line *p v* (fig. 24, plate I.) into five equal parts. Draw a line *p q* inclined at any angle, and mark off on this line five equal parts of any length; join *q*, the extremity of the five lengths, and *v*, and through the points *a*, *b*, *c*, *d*, draw lines parallel to *q v*. In virtue of a property of similar triangles these lines will divide *p v* into equal parts. It is advisable that the lines *p v* and *p q*

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should not differ very considerably in length, as, otherwise the inclination of the parallel lines to *p q* will render it difficult to observe the exact point of intersection.

To divide a line into proportional parts.—The proposition can be solved in a similar manner. Let it be required to divide a line *t r* (fig. 27, plate I.), into two sections that are to one another in the proportion of 5 to 3. On *t s* mark off a series of equal parts given by the addition of these numbers together, that is 8; and join the last point *s* to *r*. Then draw through *c*, the fifth division, a line parallel to *s r*. This line *c d* will cut *t r* into two parts, which are to one another in the proportion of 5 to 3.

By an analogous construction a fourth proportional can be graphically obtained, as already indicated in articles **25—7.**

37. To construct an angle equal to a given angle.—The angle may be measured by means of the protractor (**24**) which then enables us to draw a similar angle; but greater accuracy is attainable by using the compass.

Let it be required to construct at *m* on the line *m p* (fig. 25, plate I.), an angle equal to *b a d*. With as large a radius as possible, draw from the points *a* and *m* the arcs *b d* and *n p*. Measure the distance *d b* and mark it off with the compass from *p* on the arc *p n*. A line drawn through *m* to the intersection of the two arcs will give the required angle equal to *b a d*.

38. To subdivide an angle into 2, 4, or 8 equal parts.—In addition to the use of the protractor, the following graphic method is often given in works on geometry.

An angle *e f g* being given (fig. 30, plate I.), from its apex *f* as a centre describe the arc *e g*, and from its two points of intersection with the sides, with a radius greater than half their distance apart, draw two short arcs cutting each other at *s*. A line drawn from *f* through the intersection *s* will divide the angle into two equal parts.

If four divisions are needed, repeat the process on the

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two angles *s f e*, *s f g*, and so on for a further subdivision.

The line that divides the angle into two equal parts will also bisect or divide into two equal parts the chord and arc *e g*.

39. To find the centre of a circle or of a circular arc.—Take on the circumference or on the arc three points *b c r* (fig. 26, plate I.). Join *b* to *c* and *c* to *r*. At the middle point of each of these lines* erect a perpendicular. The point of intersection of these perpendiculars is the required centre.

A similar method should be resorted to when it is desired to describe a circle passing through three given points.

40. To connect up or associate lines.—In order to join up a straight line, such as *i j* (fig. 22, plate I.), with the curve *l p*, erect a perpendicular at *j*, and through the middle point of a chord, *l p*, draw a second perpendicular cutting the first in *k*. This point will be the centre from which the curve uniting the two lines should be struck.

To unite a curve *a b* (fig. 21, plate I.), with another curve, *c x* or *c z*, at the point *c*, first find *o*, the centre of the curve *a b*, draw the line *a o* continuing it beyond the centre; join *a* and *c*, and erect a perpendicular at the middle point of this chord. The intersection of this perpendicular with *a o*, produced if necessary, should be taken as the centre for a curve uniting *b a* with *c*.

To join up two lines inclined to each other or parallel lines of unequal length, such as *a r*, *b s*, fig. 23, draw midway between the two another line, *z d*; join the two extremities *r* and *s*, and from these points let fall perpendiculars *r i* and *s c*; then from *d* draw a line perpendicular to *s r*. The point *o* thus obtained will be the centre of the arc *r d*, and *c* will be the centre for *d s*.

* Determined in the manner explained for erecting a perpendicular in par. 32 except that intersecting arcs are described on both sides of the line (*n m*, fig. 14, plate I.); the perpendicular will be a line joining these points of intersection.

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41. To describe an ellipse.—Let *a b* (fig. 28, plate I.), be the major axis of the ellipse; divide it into three equal parts, and from the two points, *c* and *i*, at which it is divided, with a radius equal to *i c*, draw (in pencil) two circles, intersecting in the points *x* and *z*. Through these points draw the lines *x i g*, *x c h*, *z i f*, *z c d*.

With the centre *z* describe the arc *d f*, and from *x* draw *h g*; the ellipse will be completed by the two arcs, *f b g*, *d a h*, of the primitive circles.

If it be required to describe an ellipse that shall have a shorter minor axis, divide the major axis into four equal parts, thus obtaining three points of subdivision. With each point as a centre and with a radius equal to one of the spaces describe circles. Those to the right and left will determine the extremities of the ellipse, and the central circle will intersect the minor axis in two points which must be taken as centres for describing the top and bottom portions of the figure.

When the length of the long and short axes are given, proceed as follows (fig. 29):—From the centre *a*, where they intersect at right angles, mark off the distances *a n*, *a o*, equal to the difference in the length of two semi-axes. Join *n o*, and add one half of *n o* to *a o* measured in the direction *a v*, thus obtaining the point *k*; with the radius *a k* describe a circle. On this circumference will lie the four centres; *k* for the arc *r u s*, *m* for the arc *p v q*, *t* and *i* for the short arcs *q j s*, *p e r*.

The figures obtained by the methods here given closely resemble the ellipse, but are not of the strict mathematical form. It is well to acquire some facility in drawing ellipses, for the projection of a circle on a plane, when the two are neither parallel nor perpendicular, is an ellipse, and one often has occasion to describe it.

42. The following may be added as a mode of describing an ellipse:—

The major axis and the two foci (points in this axis) being

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known, fix two pins in these foci. Then tie a piece of string into a loop and place it over the pins; stretch it with a pencil, the point of which is on the paper, and on moving this round in a circular direction, the string being maintained stretched, an ellipse will be described. When the string is so stretched that it lies along the major axis, the length should be such that the pencil is exactly at its extremity.

43. To draw a spiral curve.—Draw four lines forming a small square (fig. 13, plate I.). The point *o* is taken as the centre of the first arc, *i j*; *s* is the centre of *j k*; *u* of *k l*; *i* of *l n*. Then, to continue the curve, *o* is again taken as the centre for *n p*, and so on. This method produces a volute in which the coils are at a considerable distance apart, such as has no special applicability to horology.

As the balance-spring of a watch is partially concealed by other pieces, it is generally sufficient to represent the parts that show themselves by concentric circular arcs, or arcs described from two centres. If a more accurate representation be required, the following method may be resorted to; when working on a small scale it involves the use of the eye-glass, for the figure (fig. 12, plate I.) here given is exaggerated in order to avoid confusion in the lines, numbers, letters, &c.

A small circle having been described, it is divided into an even number of equal parts, say four; a less number than this should never be adopted. From the same centre describe another circle as small as possible, which will be cut by the two diameters drawn between opposite points of division numbered 1, 2, 3, 4.

Assuming *a* to represent the starting-point of the curve, from the centre 1 with radius 1 *a* draw the arc *a b*; from 2 with radius 2 *b* draw the arc *b c*; from 3 with 3 *c* draw *c d*; from 4 with 4 *d* draw *d s*; then re-commencing with 1 and the radius 1 *s* draw *s f*, and so on.

The less the radius of the small circle and the greater its number of divisions, the closer will the successive coils be

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together. To secure accuracy when working on a small scale, it is advisable that the centre and the several points be in a thin brass or horn plate, which is maintained in position by steady pins.

THE MICROMETRICAL DIVIDING TABLE.

44. This instrument is no more than a simple application of the screw to dividing straight lines, but it will suffice to enable the reader to understand the principles on which the more complicated instruments are based.

A plate, P, fig. 1, plate II., supports a bracket *a*, in which a screw, similar to the one described in paragraph **30**, is engaged by means of a collet; it rotates, being supported between this bracket and the small bearing *b*, that receives the pivot at the end of the screw.

The screw is fitted carefully into a nut *n*, which is rigidly attached to the small plate *h*; this carries a fine marker, movable on an axis, and terminating with a chisel-edge or a fine diamond point, according as the instrument is to be used for engraving metal or glass; or it may be provided with a fine pencil if the object is merely to make subdivisions on a drawing.

This being understood, it will be evident that, if a rule or rod of any form be fixed by screws or otherwise between *f* and *g*, it can be graduated by means of the marker, the screw being made to advance; the millimetre screw can be used for dividing into millimetres and fractions direct, or, with a little calculation, into fractions of an inch. Each complete rotation of the head means a displacement of the marker by a millimetre; a half turn will be half a millimetre, &c.

OTHER METHODS OF DIVIDING A RULE INTO EQUAL PARTS.

45. First method.—Having fixed a sheet of drawing

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paper on a smooth board, draw the line M N, fig. 10, plate XI., longer than the rule which is required to be divided. Then, with a compass or graduated scale, mark off a series of equidistant points, commencing at N, equal in number to the required series on the rule, and let M be the last division. With the centre N and radius N M describe the circular arc *p v*, and with M as a centre and the same radius, describe a second arc *r s*, intersecting the first at O. Join O with M and N. Assume *a c* to be the rule that is to be divided into equal parts ; slide it on the paper parallel to M N until the extremities, *a* and *c*, coincide with the lines O M, O N, and are equidistant from O. This position can be easily found by the aid of a compass with one of its centres at O. Now fix the rule in position with sealing-wax, or by some other means, and, with a firm upright pin, centre the brass rule R at O, so that it can rotate round this centre on the pin as a pivot. It now only remains to trace a series of lines O *k*, O *b*, O *d*, &c., with the rule, to the division points of the line M N. The line *a c* is thus divided into as many equal parts as the line M N. The graduations will be all the more exact according as the divisions of the line M N are longer.

46. Second method.—By the side of the chuck of a wheel-cutting engine, arrange a horizontal slide *y f*, fig. 11, plate XI., that can travel easily in a direction perpendicular to *a* T. A watch fusee-chain, or a very flexible spring, is fixed by one end to the chuck, and by the other to the slide at *d*. The chain or spring is kept stretched by a weight which tends to draw the slide from *f* towards *d*.

The rule to be graduated, *a*, is now fixed on the slide, and an initial division is marked on it with a pointed rotating cutter in the position usually occupied by the wheel-cutter, or else by striking a small pointed or flat-edged chisel arranged for the purpose in such a manner as not to be liable to derangement.

Rotate the table through a definite distance ; the rule *a*

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will advance through the same distance; mark the second division; then having moved the division-plate through a distance equal to its first displacement, mark the third graduation, and so on. Suppose, for example, that it be required to make 30 divisions on the rule between *f* and *d*: select on the plate the circle corresponding to twice or thrice this amount, so that the radius of the chuck may not be relatively too short, and that the chain or spring may not act at a disadvantage: take the number 60 for example.

The two marks at *d* and *g* on the spring indicate the length that corresponds to the straight line to be divided.

The chuck is placed in the lathe and reduced in diameter until the half circumference is exactly equal to the distance between these two marks on the spring, which thus fall on a diameter, *i g*, of the chuck.

The spring having been fixed by its two extremities, the slide with the rule attached is placed in position, so that the mark *g* is on the line *a* T; it will be evident from the figure that each displacement of the division-plate through one-sixtieth of its circumference will cause *a* to advance through one-thirtieth of the space between *f* and *d*.

Remarks.—Knowing the relation of a diameter to the circumference (as 1 : 3·1416), we can determine the diameter of the chuck at once by calculation.

Its form should be a true cylinder, and it is well to place guides that will prevent the spring or chain from assuming a helical position.

The slide that carries the rule should be strictly perpendicular to *a* T; and the portion of the spring that is not coiled on the chuck should always be parallel to this slide.

The chuck and spring must be quite clean and smooth, and the latter should be very pliable. A greater weight will be needed to keep the spring stretched than will suffice for a chain, and it must be increased as the strength of spring is greater.

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The slide, *y f*, may simply travel over a horizontal surface between pins planted in two parallel lines. But it would be preferable to adopt some other method, for instance, to make this piece (F, fig. 11) travel with a little friction along a perfectly true cylindrical rod.

47. Third Method.—This is merely an application of the arrangement mentioned in paragraph **44**. It will be seen in paragraph **414**, that the mandril can be employed for marking off a series of equidistant points in a straight line. Knowing the pitch of the slide-rest screw, determine the distance apart in, say, millimetres, of the required divisions, and fix the rule perfectly flat on the face-plate, which must be rendered immovable by any convenient means. Then mark the first point with the drill-stock, described in article **414**. Advance the screw by the amount previously determined upon and mark the second point. After withdrawing the drill, again advance by the same amount, and mark the third point, &c. Always be careful, before making the first mark, that the screw has already travelled some distance in the direction it will continue to move, so as to avoid backlash, or loss of time.

TO SUBDIVIDE A CIRCLE.

48. To divide the circumference into equal parts.—After having drawn the circle, A, fig. 8, plate XI., draw two diameters, *d a*, *b c*, at right angles to each other, dividing the circle into four equal parts. Join the points, *c*, *a*, and divide the line, *c a*, accurately into nine equal parts.

Draw a series of circles concentric with the first, at distances apart equal to one of the divisions of *c a*, and to the number of one, two, three, &c., according as it is required to subdivide the circle, say for a pinion, into seven, eight, nine, &c., equal parts.

With a fine-pointed compass, measure off the radius of

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the initial circle A. Placing one point of the compass at *c*, the other point will give the position of the next leaf, and so on, all round the circumference. If the innermost circle A be selected for sub-division, six divisions will be obtained, and there will be one more division for each larger circle.

The operation will be facilitated by selecting the first circle, so that the line *a c* contains exactly nine divisions equal to those of some scale that is accessible. Such a circle can be easily found, by first drawing the two diameters, laying the scale in the direction *c a*, and determining by trial the radius for which the first and ninth divisions correspond to *a* and *c* respectively.

49. To divide a surface into rings of equal or proportional superficial area.—The following solution is due to M. Brocot :—

Let *a d* be the radius of a circle (fig. 12, plate XI.) that is required to be subdivided into four rings of equal area by concentric circles. Taking *a d* as a diameter, draw the semi-circumference, *a b d;* accurately divide *a d* into four equal parts, and at each point so obtained, erect a perpendicular. Through the intersections of these perpendiculars with the semicircle, draw a series of concentric circles ; they will trace out rings, 1, 2, 3, 4, that have equal superficial areas.

If it be required to divide the surface in a given proportion, divide the line *a d* according to that proportion.

The right-hand side of fig. 12 gives a special application of this method to the division into two equal areas of the interior of a barrel exclusive of the space occupied by the arbor-nut. If the mainspring accurately covers *i c* when wound up, and *i j* when unwound, it will give the greatest possible number of turns. (See *Treatise on Modern Horology*, p. 667.)

TIME.

50. Local and Greenwich time.—Greenwich time, often

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called "railway" time, is now universally used in this country; but it may be convenient for reference that a few words of explanation be here given as to the difference between it and the local time of any given place, as well as the manner in which either may be ascertained from the other. The reader who is desirous of obtaining further information in regard to time must be referred to works on Astronomy.

The earth revolves once in 24 hours, so that each of the 360 meridians or degrees of longitude passes over the zenith or point in the heavens above Greenwich or any given place in this period. In 24 hours there are 24 × 60 or 1,440 minutes, so that the interval between the passage of one meridian and the next will be $\frac{1440}{360}$ or 4 minutes.

A degree of longitude measures 69 miles on the earth's surface at the equator, and is divided, like an hour, into 60 minutes, and each minute into 60 seconds. Thus:—

1 degree of	longitude	corresponds to	4 minutes of time.
1 minute	„	„	4 seconds „
1 second	„	„	1-15th sec. „
			or 0·066 „ „

Thus it happens that, at a town 1 degree to the east of Greenwich, the sun will be visible 4 minutes sooner, and if to the west 4 minutes later than at that place. The "local" time, therefore, at the first town will be 4 minutes in advance of Greenwich, and, at the second, 4 minutes behind the Greenwich time.

51. To ascertain the difference between the local time at two places.—The meridian of Greenwich is always to be taken as a starting-point.

Find by means of a map or the index to an atlas, what is the longitude of the places, and consider each place separately in its relation to Greenwich. Convert each degree of longitude into 4 minutes of time, each minute into 4 seconds of time,

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and each second of longitude into 1-15th second of time. Adding together these three conversions for one place, we have the difference between its time and that of Greenwich: an advance if it is to the east, and a retardation if it is to the west. Repeat the operation with regard to the second place. If both are to the east or both to the west of Greenwich the difference in local time will be given by subtracting the less from the greater; if one is to the east and the other to the west, the difference is given by adding together the two local times.

Example.—What is the local time at Dublin, Edinburgh and St. Petersburg: also find the difference between that of Dublin and each of the other towns.

Their longitudes are:—

Dublin . . . . 6° 20′ west of Greenwich.
Edinburgh . . 3° 11′ „ „ „
St. Petersburg . 30° 19′ east „ „

Converting these into time, we find—

Longitude of Dublin corresponds to 6 × 4 min. + 20 × 4 sec., or 25 min. 20 sec.

Longitude of Edinburgh corresponds to 3 × 4 min. +11 × 4 sec., or 12 min. 44 sec.

Longitude of St. Petersburg corresponds to 30 × 4 min. + 19 × 4 sec., or 121 min. 16 sec.

Dublin and Edinburgh are both west of Greenwich; the difference in their local times is, then, obtained by *subtracting* 12 min. 44 sec. from 25 min. 20 sec., the result being 12 min. 36 sec.

Dublin and St. Petersburg are, however, respectively to the west and east of Greenwich, so that their local times differ by an amount equal to the *sum* of their local times, which are 25 min. 20 sec., and 121 min. 16 sec. The difference is, then, 2 hours 26 min. 36 sec.

52. To ascertain true time.—Greenwich time signals are becoming daily more and more extensively distributed throughout the kingdom, so that in most large towns true

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time can be obtained without difficulty; and, in the smaller towns, the railway companies generally telegraph time to their stations at least once a week. But such sources of information are not sufficient, and it is obviously of the first importance that every watchmaker should have at hand a certain means of controlling his regulator as often as may be requisite. Astronomers ascertain noon, that is to say the time of the sun's crossing the meridian of the place, by means of the transit instrument, a large telescope that is set so that it can only rotate in the plane of the meridian; but such a method would obviously be unsuitable for the use of watchmakers, if only on the ground of expense.

53. *The Dipleidoscope.*—To supply a substitute for the transit instrument, Mr. Bloxam designed this instrument, which is manufactured by Messrs. E. Dent & Co.; a very brief account of it must here be given.

Two plane reflectors and a plate of glass arranged to form an equilateral prism, the two reflecting surfaces being turned inwards, are so placed that the light of the sun falling on the plate of glass is partly reflected and partly transmitted so as to be reflected by the two reflectors successively, and then again pass through the glass to be received in the eye of the observer. It may be shown that, if the angle between the incident rays and the plate be exactly 60° in this instrument, the two images thus produced will exactly coincide; but if it differ by even a very slight amount they appear distinct. If, therefore, the instrument be so placed that the sun's light falls at this angle at the instant of crossing the meridian, this instant can always be ascertained by merely observing when only one image is visible. Knowing local noon, true Greenwich noon can easily be calculated from it by the aid of tables. The necessary observation is extremely simple, and its correctness depends solely on the accuracy with which the instrument is adjusted, and on the care with which the reading is taken. True time can be determined to within a second by this means.

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PART II.

MATERIALS EMPLOYED IN HOROLOGY; THEIR PREPARATION, TREATMENT AND APPLICATION.

Metals and Alloys.

IRON.

54. Iron is an elementary body, that is to say it cannot be decomposed. It is the most tenacious of the metals, having a breaking strain of about 75 kil. per sq. mm. (or 106,000 lbs. per sq. inch) of section. Two pieces can be perfectly welded together when raised to a white heat.

In the smaller horological appliances, the metal is not employed except after conversion into steel. In common clocks it is used from motives of economy, for forming pins, screws, &c. In turret clocks, however, considerable use is made of it, many of the parts after they are formed being cemented, that is to say, having their surface rendered hard in a manner subsequently indicated (**65**).

Such a mode of manufacture is particularly applicable to pieces that are subjected to a constant succession of impacts; their hardened steelified surface resists wear, while the iron core affords security against rupture.

It is important to carefully distinguish the cases in which

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iron is preferable from those in which its substitution for steel serves merely to augment the profits of the manufacturer.

The fracture of a good piece of iron is characterized by long twisted fibres of a brilliant white colour.

If heated frequently or carelessly, the quality of the metal is impaired—it ceases to be fibrous and loses its tenacity: in this condition it is said to be *burnt.*

It is better to work with a wood fire, as coal acts more rapidly in rendering the metal brittle. Cold hammering, or "hammer-hardening," also makes it brittle and diminishes its tenacity, but this is again restored by a suitable annealing.

Iron dissolves slowly in dilute nitric acid; if not diluted, this acid rapidly oxidises it. Dilute sulphuric acid dissolves the metal easily, but if concentrated, it has no action in the cold, whereas, on heating to ebullition, the iron is dissolved with evolution of sulphurous acid gas. It is also dissolved by hydrochloric acid, or aqua regia (**155**).

Iron is less magnetic than steel, especially hardened steel, which, owing to its great coercive force, is magnetized with greater difficulty, but retains its magnetism for a longer period. Indeed, *soft iron,* if properly prepared, can be magnetized and demagnetized instantaneously.

Some workmen can distinguish iron from steel by the musical note emitted on striking. A more certain method, however, consists in using dilute nitric, or sulphuric acid. If the surface remains unaltered, or nearly so, when touched with a drop of either acid, the metal is iron, but, in the case of steel, a black mark will be left, owing to the liberation of carbon.

55. To remove rust.—The usual mode is to rub the object with a piece of oiled rag, or emery paper. It appears that more rapid and more satisfactory results are secured by using very pure petroleum, and wiping with a hempen or woollen rag.

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56. To prevent rust.—Dip iron or steel articles in a mixture of equal parts of carbolic acid and olive oil, rubbing the surface with a rag. Others rub the metal with a mercurial ointment, leaving a thin layer over the entire surface. It is stated that, if iron be dipped in a solution of carbonate of potash or soda in water, the surface will be protected against rust for a long time, and objects can be protected for any period by burying in quicklime. Rubbing the surface with plumbago has a similar effect, and Barff has pointed out that, by exposing iron to the action of steam, heated above the boiling point of water, a coating of magnetic oxide of iron is formed, which is equally serviceable.

57. To restore iron and steel that have been burnt, or badly forged.—When iron is burnt, or carelessly forged, it becomes crystalline and brittle; in order to restore it to its original condition, a fresh and very careful forging is generally needed. This can be avoided by having recourse to the following method, suggested by Caron: it consists in treating the metal somewhat after the manner adopted in hardening steel.

He experimented with a bar of good iron, which was easily bent when cold, without breaking or showing any cracks. It was then burnt and became brittle when cold, the fractured surface showing brilliant shining facets.

Prepare a boiling saturated solution of sea salt, heat the piece of iron to bright redness, and plunge it into the bath until it is of the same temperature (about 110° C. or 230° F.) After undergoing this operation, it is found that the metal can be easily doubled in the cold, exactly as it did before being burnt.

Perret states that steel which has been deteriorated by frequent hardening can be restored as follows: Heat it short of dull redness and quench in melted tallow, repeating the operation, if necessary, when the steel may be again hardened in the ordinary manner, and will be nearly, if not quite, restored to its original condition.

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CAST IRON.

58. This is only used in the manufacture of tools and large clocks; the employment of cast iron wheels in the striking train of such clocks has materially reduced their price.

Like steel it is a compound body, consisting mainly of iron and carbon. Cast iron, however, differs from steel in the quantity of carbon present, for whereas its proportion in cast iron varies from 2 per cent. upwards, there is never, in steel, an amount exceeding 1·5 per cent., and even 0·5 per cent. renders an iron hard, converting it into "mild" steel.

Cheapness is not the only argument in favour of the use of cast iron. In virtue of its molecular structure, this material offers a considerable resistance to a crushing strain, so that the teeth of wheels made of carefully selected cast iron will work for a long time without sensible wear; moreover, the founder's art has made such important advances that there is no difficulty in casting, to a constant pattern, a wheel, together with the pinion that it carries, and any other projections, &c., that may be required; this economizes labour to a very great extent.

The use of cast iron in the construction of certain classes of wheels, and parts of tools, presents advantages which we cannot afford to ignore; but it must be carefully observed that this material is not suitable in cases where great accuracy in the acting parts is required, as it cannot, like brass and steel, be conveniently worked by the turning tool or file. In recent years, however, this difficulty has been overcome by the introduction of what are termed "malleable castings," produced as follows:—

59. Malleable castings.—The object is first made of ordinary cast iron, and the invention consists in rendering this malleable by the removal of the carbon that has served the very important purpose of rendering the metal fusible. In large cast-iron pots, the castings are laid with alternating

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layers of powdered red hæmatite, and the whole is kept at a temperature of about 900° C. (1,650° F.), or cherry-red heat, for 72 hours. On cooling, the castings are found to consist of nearly pure iron and to be perfectly malleable, and, therefore, workable.

STEEL.

60. The treatment of steel involves some of the most prolonged and delicate operations in the entire range of horology. If the metal is badly selected and prepared the working of it will be laborious, difficult and unsatisfactory; the resulting object will be distorted in the hardening and will not harden uniformly; in short, it will occasion much toil and loss of time with very little success.

Let the young watchmaker accustom himself from the first to study the steel that he uses, so that he may be thoroughly cognizant of both its advantages and defects; he will, in the practice of his art, be amply repaid for the brief time spent in making such an examination.

61. Steel is not an elementary body; it is usually regarded as a carbide of iron, that is to say a combination of carbon and iron. Analysis, however, proves other substances to be usually present in almost infinitesimal quantities; their remarkable influence on the physical properties of the metal has not yet been fully investigated, but much attention is being devoted to them at the present day.

The varieties of steel are very great. What are known as *puddled* and *natural* steel are obtained by acting directly on cast iron. *Cementation* is a very old method of converting bars of malleable or pure iron into steel by enclosing them in charcoal and heating the whole for several days until the carbon has worked itself into the centre of the bars in such quantity as to convert the iron into steel.

The steel obtained by the above method is very heterogeneous; in other words, the composition is not uniform throughout a given block or bar. One part is highly car-

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bonized, whereas another part, especially towards the centre, will not be sufficiently so. The *grain*, although very fine in one part, will be more coarse in another; hard particles of pure cast iron, termed "pins," are to be met with that resist the action of the graver or the file and give rise to cracks in the hardening, hammering, &c., and portions or sometimes even entire layers that have taken up no carbon whatever. The differences in the density, hardness, malleability, &c., that can be shown to exist at different points in the same bar arise from this cause.

Such faults can in part be corrected by *shearing*, an operation which consists in binding together a number of bars in a bundle, raising them to a red heat and beating them with sledge or steam hammers so as to weld them into one. The bar thus obtained is again heated, folded several times on itself, again hammered, rolled, &c., when it is termed *shear steel*. If these operations are performed carefully and without a too great heat, the quality of the steel is much improved; it is more homogeneous and can be worked with greater facility.

62. The discovery of the earliest method of producing *cast* steel, thoroughly homogeneous, was made by a watchmaker, B. Huntsman, of York, and metal produced by his method is very highly prized at the present day. Many other methods have been since introduced, amongst which may be mentioned the Bessemer and the Siemens-Martin processes, and steel is now produced from iron of very varying quality, so that the mark *cast steel* is now far from being a guarantee of quality. The fusion of shear or cement steel will only secure a marked superiority in its quality under two principal conditions: (1) The metal must be carefully selected, since certain qualities do not intermingle thoroughly; (2) Very great care and skill must be devoted to all the operations, the successive heatings, forging, rolling, &c.

In short, in the case of steel it is exceptionally true that

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we must never accept the metal merely on its own recommendation. Whatever maker's mark is selected, the results obtained will never be satisfactory unless the degree of hardness, the elasticity, cohesive force, &c., are such as will suit the metal to the special purpose to which it is to be applied as well as to the working it will have to undergo. *Experiment can alone make us fully cognizant of the qualities of a steel.*

GENERAL OBSERVATIONS.

63. All steels, if of good quality to begin with, will deteriorate if subjected too often or too long (according to the character of the metal) to the action of either the fire or the hammer. They will become brittle and incapable of hardening, in the end even reverting to the condition of iron.

The quality of a steel becomes worse as the number of flaws, blackish filaments, more or less carbonaceous veins, and occasional particles of pure iron in its substance are greater; as its surface is *cindery*, that is to say spotted with minute black marks which become more prominent after polishing, &c.; as its fracture presents an uneven grain, &c.

Such a metal is found to vary considerably as regards hardness, elasticity, &c.; not being uniformly affected in the hardening, it becomes difficult to work with the file and almost impossible to form into a perfect cylinder in the lathe.

Other conditions being equal, these faults are characteristic of natural steel rather than of the two other varieties. At the same time, if well sheared, it becomes very elastic, and has the great advantages of not being deteriorated under the hammer and of being less ready than the other varieties to be converted into iron.

Rolling, wire-drawing and hammering occasion a molecular re-arrangement; it is necessary, therefore, to anneal

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the metal from time to time, as otherwise it becomes brittle or cracks.

There is a certain temperature, corresponding to each variety of steel, which cannot be exceeded without the metal being injuriously affected; this temperature must, then, be previously determined.

The grain of a piece of steel that has been super-heated or *burnt* is characterized by brilliant diamond-like particles; the mass loses its beautiful colour, and resembles iron more or less according to the degree of heat applied.

Some few workmen are enabled, by long experience and a very delicate touch, to judge approximately of the quality of a steel from its weight, feel, and resonance. Metal that is of a good quality, homogeneous, and very dense, they term *full*.

SPECIAL OBSERVATIONS.

64. Natural steel.—In the case of natural steels of low quality, the fracture is usually characterized by uneven grains, a somewhat fibrous nature and a bluish tint. The grain becomes finer and more even and the surface presents more and more the appearance of a piece of coke, as the quality of metal improves. In addition to these distinctive features a natural steel of high quality can be distinguished by the fact of its being more thoroughly hardened and less liable to break when hard.

In hardening it must be raised to a higher temperature than cement steel; in other words, steel of a low quality must be heated somewhat above bright redness, while the better qualities should be heated to an orange-red, or nearly so (**77**).

65. Cement steel.—The cement steel ordinarily met with has a lamellar fracture, the lamellæ varying in form and colour from the centre towards the circumference. The grain is usually finer and more uniform than that of natural steel, there is seldom any appearance of fibres, veins, or

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flaws. The colour of the fracture is greyish tending towards blue in the ordinary qualities.

The better qualities are marked by a closer grain, a more uniform dull greyish-white colour, exhibiting neither streaks nor black spots after hardening, and by the further fact that hardening can be effected at a lower temperature. If of the very best quality, it should not require heating beyond a clear cherry-red; often even a still less degree of heat will suffice.

66. Cast steel.—Cast steel is the most homogeneous, full, and beautiful of the three classes. Several varieties exist.

The fracture of cast steel as compared with others is smooth, compact, and of a white-grey colour, resembling coke. The grain is fine and very even. The metal must be hardened at a temperature much lower than can be safely applied to other classes of steel, since it is rapidly deteriorated by heat.

Cast steel is more fusible than ordinary steel, and will fracture with ease under the hammer when heated to a blue tint, so that great care is essential in hammering it.

The metal should never be heated beyond a dull or cherry-red heat, lest it be *burnt*.

The tenacity will be increased by forging at a low temperature or even by cold hammering.

The fineness in grain, together with its high density, afford an indication that the metal can be rendered very uniformly hard; that very fine cutting edges and the most minute rods can be made of it; and that, after hardening, it can be highly and uniformly polished; in other words, that it does not exhibit spots or streaks differing in colour from the mass, as is always the case with natural and cement steels.

For most horological purposes (such as making pinions, staffs, pivots, &c.) cast steel is preferable. It is the only kind that can with certainty be highly polished, turned

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perfectly round, and that does not get distorted in the smoothing. Moreover, when wear does occur it exhibits less irregularity.

Highly-carbonized shear-steel exhibits a fine close grain that would make it easily mistaken for cast steel. They can be best distinguished by the application of dilute sulphuric acid. The side of the bar when acted on by this means exhibits lines that indicate the junctions of the several layers constituting shear-steel.

EXPERIMENTAL DETERMINATION OF THE QUALITIES OF STEEL.

67. It is unnecessary to observe that as we are writing mainly for the use of practical watch and clockmakers, we shall make no reference to those elaborate systems of testing that form a remarkable feature of the engineering of the present day, but shall confine ourselves to the tests which workmen can apply for themselves.

When the grain is fine, close and homogeneous, the fracture in even curved lines and the surface of a uniform grey aspect, the metal is considered to be of good quality. It is, nevertheless, unsafe to rely too much on such indications, for a steel that has been hammered until cold will exhibit a fine, close grain, whereas the grain of the same metal will be coarse and open if it was still red-hot when the hammering or rolling was concluded. The grain of hardened steel, moreover, depends on the degree of heat to which it has been subjected.

When of equal quality, even if from the same maker, the grain will be finer in bars of small dimensions than in those that are larger.

Cast steel even, especially in large pieces, is not always perfectly homogeneous, as can be easily perceived on applying the file, or still better, in the lathe ; an object can with difficulty be turned perfectly round, and loses its shape in

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the smoothing. *As a general rule it is impossible to form a reliable opinion on a specimen of steel until after it has been worked, filed, turned, and tested according to the particular use to which it is to be applied; for a steel that is excellent for making, say, a spring or a cutter, may be quite unsuitable and give most unsatisfactory results if used for making staffs or fine pivots, or the converse may be equally true.*

As a preliminary test, break a piece of the metal; after having examined the fracture, form a cutting edge, harden to what seems to be a convenient degree, then sharpen and employ for cutting small pieces of iron. If the edge is in no way damaged by the iron, this may be taken as a good indication that the metal possesses body and tenacity, and that it can be hardened as much as is required for such purposes.

The following are methods of obtaining more complete information as to the homogeneity, the character of grain, the degree of hardness a given sample can attain; as well as its malleability, body, elasticity, &c.

68. Homogeneity.—Place drops of dilute sulphuric acid equidistant along the surface of a bar. If the metal is homogeneous all the drops will impart the same colour.

Cold hammer or hammer-harden, and then fire-harden part of the bar. Break off the extremity in order to study the fracture; if the result of this examination is satisfactory, polish the hardened end carefully, and with the aid of a glass again examine into the homogeneity of the metal. The polish will be the better and more uniform according as the steel is more homogeneous.

69. Grain, hardness and temperature of hardening.—All varieties of steel do not harden to the same degree, and each requires to be heated to its own particular temperature for hardening; moreover, the character of the metal, its colour, and the size of its grains vary according to the degree of heat to which it is subjected. It would be difficult to draw any exact conclusions as to the character

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of grain and the hardness without the following practical method, which we owe to Réaumur :—

At a temperature not exceeding a dull redness, forge a piece of the steel to be tested into the form of a razor-blade, that it is to say, leaving it thick on one edge and thin on the other, in the direction of its length. Then heat the blade, holding it by one end, and when the other end has reached a bright red heat, plunge the whole into water. Part of the steel will then be hard hardened. Along the entire length of the thinner edge carefully break off the metal with a hammer or otherwise, and examine the character of grain at different points of the exposed thicker edge thus left.

As the form, colour, &c., of the grain depend on the degree of heat to which each portion was subjected, it follows that we shall observe four types of grains :— (1) Large, white, sparkling grains ; (2) Grains that are medium sized and intermixed, some being white and sparkling, others white and dull ; (3) Fine dull grains ; and (4) Grains that are medium sized, but dull and ill-defined.

According as the third class of grains is observed to be more numerous than the second class, so is the fineness of the steel greater, and conversely.

This method of testing possesses, moreover, the advantage that the workman can experiment on his blade of steel with a view to determine the temperature best suited for hardening.

Generally :—

Grain No. 1 corresponds to a white-red heat for hardening.

Grain No. 2 corresponds to an orange-red heat for hardening.

Grain No. 3 corresponds to some shade of cherry-red heat for hardening.

Grain No. 4 corresponds to a dull red heat for hardening.

As there is some difficulty in remembering the exact points at which these several temperatures are reached we

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will complete this account of the mode of testing by the following :—

70. On a thick plate of metal, maintained at an orange-red heat, place three fragments of the steel under examination, previously marking them, so as to observe the order in which they are immersed in water ; and have three vessels of water standing near. As soon as one of the pieces reaches a dull cherry-red heat, allow it to slide into one of the vessels ; heat the second to a medium cherry, and the third to a bright cherry-red, introducing them in succession into the water vessels. If these pieces be examined as to the resistance they offer to breaking, and the fracture of each be compared with the fracture at different points of the razor-blade, the file being used to test hardness, we shall have sufficient evidence as to the most suitable temperature for the hardening of this particular variety of steel.

71. Body.—A steel that possesses *body* is not brittle. This quality may be tested in the following manner :—Several bars of different kinds of steel, of equal dimensions and hardened as uniformly as possible, are bent until the breaking point is reached. If all the conditions of the trial are identical, those bars that stand the greatest angular deflection without breaking have the most body.

Steel that possesses body does not break as easily as that which is wanting in body. Its fracture will be as it were bevelled off like the mouth-piece of a whistle. If soft and fibrous, it will be characterized by parts being torn asunder.

72. Elasticity.—The elasticity may be tested in a similar manner. It is proportional to the curvature or to the weight that a rod or blade of the metal under examination can support without failing to return to its initial position as soon as the weight or obstacle is removed. A sample of steel that is distorted by a weight that another specimen resists, is evidently inferior in elasticity.

73. Malleability, tenacity, ductility.—A cold ham-

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mering, if carefully managed, will suffice to indicate the limits between which steel will support frequently repeated percussion without breaking, cracking or flying.

Forge a piece, introducing it a number of times into the fire in order to ascertain whether it loses its distinctive characteristics rapidly, and whether it can be successfully forged.

It is more difficult to forge according as it is harder and more "steely."

The degree of malleability is indicated by the manner in which it supports hammering and rolling, and by the smallness of the dimensions to which it can be brought by such operations.

Passing the metal through a draw-plate with smooth holes, or tapping it in a screw-plate will give useful indications as to degree of ductility and tenacity.

A metal is said to be *malleable* when it can be easily spread out under the hammer or in the laminating rolls. It is called *ductile* when it can be reduced to very thin wire by passing through the draw-plate.

It would seem that these two properties, ductility and malleability should always exist together to the same degree in any given metal, but such is not the case. Iron can be drawn into very fine wire, but cannot be reduced to sheets of relatively equal thinness; tin and lead give leaves of extreme thinness, but cannot be drawn out into very fine wires; gold and silver are both very malleable and ductile, and they rank highest as regards the possession of these properties.

Steel is more fusible and malleable than iron but less ductile.

74. *Observations.*—Formerly the makers of cylinder escapements preferred forged steel, and their cylinders often cracked after the hardening: modern makers employ drawn steel and it is much preferable. At the same time they do not appear to recognize the principal reason for the difference in the two varieties of steel. It seems to us to be as follows:

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forged steel is malleable; drawn steel, which has passed well through the draw-plate, is ductile and therefore tenacious. But tenacity in a metal is nothing else than an exceptional resistance opposed by its particles to fracture or separation; it follows then that drawn steel will crack with less facility than the other.

PREPARATION OF STEEL.

75. When a variety of steel has been selected that possesses the requisite properties: that is to say, fibre and elasticity for springs; body and tenacity for circular cutters, gravers, &c., it must be "prepared;" in other words it must be made so that it can be worked with ease, for steel that is badly prepared will resist both the file, the graver and the drill. It can never be turned perfectly round, and will harden unevenly.

76. To anneal steel.—The commonest and, at the same time, best method consists in heating the metal to a dull red heat, burying it in hot ashes and allowing it to cool slowly.

Steel raised to a red heat in contact with air loses a portion of its carbon, so that it is better to place the metal in a vessel of burnt clay; this is introduced into a fire which must not be too bright at first, and, when the vessel has attained a red heat, the fire is checked and left until the whole is quite cold.

In order to soften steel by annealing with a view to work it, engineers entirely cover the metal with dry powdered wood charcoal or dry iron filings or turnings in a cast-iron box or pot or in a crucible, luting up all the openings so as to protect it from the direct action of the fire and from the air. The vessel is then put in a dull fire, the heat being gradually raised until the whole has acquired the requisite temperature, which is known by observing the colour (see the table opposite); this degree of heat is maintained for about ten minutes and the fire quenched, after which it must be

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allowed to gradually die out. Frequently the cooling is not complete for a day or two, and even more when the crucible is of large dimensions.

The metal will become softer according as the cooling is the more slowly effected. It is generally heated to 800° or 900° C. (1500° or 1600° F.), a cherry-red heat. When the steel is associated with brass, as in the case of a compensation balance, it is not safe to exceed 600° C. (1000° F.).

77. It will be useful here to give the following table, compiled by Pouillet, of the temperature, as indicated by the air-thermometer, corresponding to various colours of a heated body:—

Incipient red heat	corresponds	to	525°C.	(980°F.)
Dull red	„	„	„	700°C.	(1290°F.)
Incipent cherry-red heat	„	„	800°C.	(1470°F.)
Cherry-red	„	„	„	900°C.	(1650°F.)
Clear cherry-red	„	„	„	1000°C.	(1830°F.)
Deep orange	„	„	„	1100°C.	(2010°F.)
Clear orange	„	„	„	1200°C.	(2190°F.)
White	„	„	„	1300°C.	(2370°F.)
Bright white	„	„	„	1400°C.	(2550°F.)
Dazzling white	„	„	1500-1600°C.	(2730-2910°F.)

78. *Annealing or softening in water.*—Instead of allowing a piece of steel to cool slowly, it may be thrown into water when heated to a temperature just below that at which it would harden. In this case the metal will not harden but, on the contrary, it will become very soft. A single operation suffices for certain varieties of steel, but with others it must be repeated.

The only difficulty consists in fixing upon the precise moment at which the metal has the requisite tint (a purplish yellow or dull red), and this is more especially felt when dealing with small pieces; experience can alone guide the workman in this matter.

A skilful workman recommends the employment of

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water containing one-fifth of its weight of gum arabic. He also recommends that the metal be wiped over with an oiled rag, then held in the fire, and as soon as the oil is converted into a thick smoke and is on the point of igniting, to immerse in water.

79. Hammering steel.—Watchmakers, who are called upon to manipulate exceedingly small pieces of steel, can somewhat increase the body and homogeneity of the metal by a cold hammering. After annealing, the object is hammered with light, uniform blows, again annealed, and the same operation is repeated one or more times, according to the degree of malleability already acquired by the metal. Steel thus prepared has more body; the particles composing it are more closely pressed together; it files and turns well, can be heated more evenly, and is not distorted or only very slightly in hardening, providing the requisite precautions are taken.

80. *The hammer and anvil.*—It is important that in these operations the surfaces of the hammer and anvil employed be perfectly smooth and even polished. If they are at all rough or cracked, if they are uneven or have a grainey surface, a flaw will be produced in the body of the steel or a crack on its surface.

81. To clean rough steel.—The black coating, known as "scale," which covers the surface of the metal after it has been in the fire, will rapidly spoil gravers and files, and, in addition to this, it leaves behind in them excessively hard particles that will become embedded in the steel itself after a clean surface has been exposed. It is then essential, in order to ensure good and rapid workmanship, to previously remove this crust from the surface.

This can be done in two ways: by using a rapidly-revolving grindstone, which instantaneously removes the oxide, at the same time smoothing the surface of the steel; or by leaving it for a sufficient length of time in dilute acid, by which the superficial oxide is dissolved.

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Sulphuric acid is usually preferred; in addition to the cleaning, it is said to produce an effect somewhat similar to annealing. On withdrawal from the acid, the steel must be thoroughly washed with water and wiped dry with care.

82. Ordinary mode of preparing steel.—When the metal has been annealed by one of the methods indicated above, its preparation is completed by the "pickling" in acid, after which it is hammered cold between an anvil and hammer (**79, 80**). When the metal has been worked, it is heated to a bluish tint, and after cooling slowly is ready for the hardening.

83. *M. Covillot's mode.*—This author adopts a method whereby he obtains steel that is very soft to work and perfectly free from hard grains or "pins" of cast iron, which are so often to be met with in steel, causing it to crack in consequence of their inability to spread under the hammer.

Take some garlic, the younger the better, mix it with sufficient good walnut-oil to cover the garlic and form into a paste; then place it in an earthenware pot on the fire. When beginning to boil, heat the steel to dull redness and plunge into the boiling paste. Withdraw it with a quantity of oil and garlic adhering; again heat to redness and plunge into the paste. This operation may be repeated two or three times. Then heat the steel, while enclosed in an iron tube or box placed on the fire, and allow the whole to cool. Finally, the steel may be finished by setting it to *cook* (if we may use such an expression) for ten or twelve hours in the composition of garlic and nut-oil.

This last operation may be performed by setting the boiling solution over an oil-lamp, after depressing the wick in such a manner that the paste may be kept just simmering.

M. Covillot employed the same mixture for hardening the objects; but then, of course, it must be cold.

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HARDENING.

84. It is well known that by the operation of hardening, which consists in heating a piece of steel to a red heat and immediately chilling it, the hardness is very materially increased.

Hardening increases the dimensions of the object. A steel collar adjusted to fit a cylinder will slide on more easily after hardening.

Rolled steel is more liable to be distorted in the hardening than metal which has been forged or hammer-hardened. As a general rule, when steel—especially cast steel—has been carefully annealed, cold-hammered and, after working, heated to a blue temper and slowly cooled, it will not be distorted in the hardening, providing the heating is skilfully conducted, and if, at the moment of introducing the object vertically into the bath, the heat is evenly distributed throughout. Some practical men affirm that the mere presence of an oily layer on the surface of the water will check the tendency to distortion.

A workman frequently pretends that he has some exceptionally good solution for hardening, of which a great mystery is often made; but it is very generally admitted by those who are well-informed that these so-called secrets are a delusion and in no sense superior to pure water. There is a certain amount of truth on both sides, and the former class are somewhat justified by experiments with the various solutions enumerated below. We may, however, lay down the three following conditions as essential to the successful conduct of the operation of hardening :—(1) *The steel must previously be carefully prepared and worked;* metal that has been skilfully hammered cold or below a red heat, for instance, will harden better than when not so treated; but if hammered too much or carelessly, it will crack; (2) *The method of heating* should be such that the heat is evenly distributed

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throughout the object; if, on immersion, its temperature is not uniform, the degree of hardness will vary; (3) *The skill of the workman* must enable him to detect the exact degree of heat the variety of steel can withstand, and this must on no account be exceeded, for in that case the steel will lose tenacity, will be more or less *burnt*, &c. In the case of irregular-shaped articles, considerable skill is also often needed to ensure that the several parts of the mass shall be cooled at, approximately, the same rate.

85. Methods of hardening.—The baths used for hardening may be classed under three heads: *Tough*, *Hard*, and *Glass-hard*. It must be understood, however, that these classes may be made to merge more or less into one another, by varying the degree of temper (**88**). The following receipts are drawn from various sources, and the reader is recommended to select the one which he finds on trial to be best adapted to his requirements, for, as Prof. Akerman has pointed out, there are very many conditions exceedingly difficult of calculation that influence hardening, and hence it follows that a workman accustomed to hardening often considers that only one method, which he has been in the habit of employing, can be used for a certain purpose, while another equally skilful workman can only attain the same result by a method essentially different.

I. *Tough.*—Tallow; tepid water; oil; resin; sealing-wax; lead; beeswax; a solution of 3 to 4 parts (by weight) of gum arabic in 100 parts of water; 1 part of soft soap in 100 parts water; cold water with a layer of oil over it, the thickness of which varies with the degree of hardness required; 10 parts mutton suet, 5 parts resin, 2 parts sal-ammoniac, and 35 parts olive oil.

II. *Hard.*—Cold water; water containing various salts, such as sal-ammoniac and sea-salt; a solution of 5 parts sea-salt and 1 part sal-ammoniac in 20 parts of water; 4 parts sulphuric acid, 50 parts sea-salt, 10 parts alcohol, and 1,000 parts water (all by weight); 4 parts sulphuric acid, 1

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part nitric acid, 1 part pyroligneous acid in 1,000 parts water (to be used very cold).

III. *Glass-hard.*—Mercury; nitric acid; opium; any cyanide.

86. As a rule it is well to employ tallow for the hardening of small objects in which hardness without brittleness is needed. Oil renders the surface harder than the interior, and soapy water has the same effect. Saline solutions generally give great hardness. Very minute drills may be hardened by simply whisking them about in the air after heating the blade to redness, and small objects may be hardened by pressing between two cold surfaces, as those of the hammer and anvil.

If hardened in nitric acid, opium, or mercury, the hardness of steel is so great that it will easily cut glass. But such steel is brittle and all the more delicate according as the precise temperature necessary (which is not very high) has been exceeded. For it must always be borne in mind that steel which has been heated too highly has deteriorated in quality and will remain brittle.

Certain special methods of hardening will be found in the *Treatise on Modern Horology*, to which we refer the reader. These are:—

To harden a cylinder, p. 263; a cylinder escape-wheel, p. 283; a chronometer balance-spring (Houriet's, Motel's, Rozé's, and other methods), p. 770.

87. Precautions to be observed in hardening.—In the case of delicate pieces it is necessary to avoid the use of the blow-pipe, as the current of air causes the surface to scale, and, as is well known, the metal being unevenly heated will be distorted in the hardening, and will not be uniformly hardened.

It is better to enclose the article between two pieces of ignited charcoal, or in a metal tube, or to bring it in contact with a sufficiently hot piece of metal, &c. An excellent plan is to heat the article in a bath of hot lead, or of lead

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and tin in proportions dependent on the temperature required. The heating is thus exceedingly uniform, and, if operating in a dark room, the temperature can be accurately judged.

When it is required to harden an object without discolouring the surface or destroying the polish, it may be placed in a tube, and completely surrounded with powdered wood charcoal or, preferably, animal charcoal. The whole after being heated is plunged in water without the steel being in any way exposed to the air. The powder must be heaped up as a precaution against access of air. On being taken from the water, the steel is at once placed in alcohol, and if at all dull it will generally be only necessary to rub the surface with a little rouge.

It is essential that the animal charcoal be previously heated in order to expel moisture, as otherwise it would adhere to the surface and produce marks and even irregularity in the hardness.

As a rule the object must be immersed in the cooling liquid vertically in the direction of its greatest length, and if of unequal thickness the stout portion should touch the surface first, so that the metal may cool more uniformly. In hardening large masses of steel, various devices are resorted to in order to ensure uniformity in the cooling,* but space prevents us from entering more fully into this interesting question.

The vessel must be of such a depth that the object will not reach the bottom until quite cold. It is liable to distortion if introduced sideways, or if the vessel is too shallow.

The method described above for protecting the surface from the action of the fire should be adopted when hardening delicate or complicated articles; but in the case of drills, for instance, a simple coating of one of the following preparations is sufficient.

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* Ede: *Management of Steel.* London. 1873.

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When an object is hardened in a saline solution, it is well to cover it with a paste composed of water, salt and flour (some use yeast and salt for this purpose), or a thin clay. This precaution prevents any blistering or oxidation of the surface. If it be desired to avoid oxidation, and, at the same time, to restore to the steel the carbon it has lost owing to the action of the fire, it must be rolled, while still wet, in another paste, containing powdered horn or leather, or some such calcined animal matter. Delicate parts can also be protected by a layer of beeswax and olive oil made hot.

In hardening small drills, very good results are obtained by enclosing the blade in a pellet formed of prussiate of potash, lard and Castile soap, and cooling in beeswax. Or the surface may be protected by a layer of soft soap.

Steel as forged, that is with the thin scale on, is less liable to break in hardening than if previously brightened, for the scale causes it to cool, and, therefore, contract more slowly. At the same time, it should be borne in mind that, when the surface is bright, the hardness will be somewhat greater.

It will be well to warn the beginner that, if an object is not entirely immersed in the cooling liquid, it should never be held still, but rapidly moved up and down, as otherwise there is a liability to crack at that part which was level with the surface.

As a watchmaker only uses steels of the best quality, he should, in hardening, never exceed a cherry-red heat, and cherry-red comprises three distinct tints (**77**); incipient cherry-red, cherry-red, and clear cherry-red. The second of these should not be exceeded in hardening cast steel, and the third should be taken as an extreme limit in the case of shear steel.

Ice-cold water should never be employed, but the extreme chill should be first taken off. Indeed, it is found that frosty weather interferes materially with the operation of hardening.

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Some workmen maintain that the hardening is done better if the water has been long used for the purpose without renewal.

TEMPERING.

88. Hardened steel is extremely fragile, but its tenacity may be restored by *tempering*, that is to say, by heating it to a degree dependent on the amount by which its original softness has to be restored. The colour of the metallic surface will gradually change as the temperature rises, each tint corresponding approximately to the degree of heat given in the following table (Stodart) :—

1. Very pale straw yellow ..	220°C. (430°F.)	Tools for metal.
2. A shade darker yellow ..	235°C. (450°F.)	
3. Darker straw yellow	245°C. (470°F.)	Tools for wood and screw taps, &c.
4. Still darker straw yellow	255°C. (490°F.)	
5. Brown yellow	260°C. (500°F.)	Hatchets, chipping chisels, and other percussive tools, saws, &c.
6. Yellow, tinged slightly with purple	270°C. (520°F.)	
7. Light purple	275°C. (530°F.)	
8. Dark purple	290°C. (550°F.)	Springs.
9. Dark blue	300°C. (570°F.)	
10. Paler blue	310°C. (590°F.)	Too soft for the above purposes.
11. Still paler blue	320°C. (610°F.)	
12. Still paler blue, with tinge of green.....	335°C. (630°F.)	

89. It will facilitate the precise determination of these points if it be remembered that—

An alloy of 1 part lead and 1 part tin (by weight)	melts at	196°C. (385°F.)
Metallic tin ,, ,,	,,	230°C. (446°F.)
An alloy of 2 parts lead and 1 part tin	,,	240°C. (465°F.)
Metallic bismuth ,, ,,	,,	270°C. (520°F.)
An alloy of 5 parts lead and 1 part tin	,,	290°C. (550°F.)
Metallic cadmium ,, ,,	,,	310°C. (590°F.)
Metallic lead ,, ,,	,,	320°C. (608°F.)

90. Before proceeding to temper an object, at least one of its faces must be smoothed with pumice stone, oilstone dust, or emery paper, and the surface must be left perfectly

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clean, care being taken to avoid contact with the fingers, as otherwise it will be difficult to ensure the requisite tint being obtained.

Tempered to any shade between Nos. 1 and 6 the steel will, if previously well hardened, be left too hard to be worked by a file or graver; heated beyond No. 10, it can no longer be much bent without distortion.

When the quality and the degree of hardness of steel differ, the temper corresponding to a given tint will also vary. As a rule, hardened cast steel, tempered to No. 8, will be found as soft as natural steel which has been let down to No. 9, or even to No. 10.

A piece of steel can be let down to the same tint several times in succession without altering its properties.

If a good and uniform colour is desired, the steel must be highly polished, as the oxidation of rough parts will render the tint irregular. The rouge employed must not be too dry, and, if the burnisher is used, care should be taken that it acts on the entire surface. Metal of a bad quality, which will not take an even polish, can rarely be nicely blued.

When the object is finely *smoothed* with a uniform white surface, very good results may be obtained; but in such cases the cleaning must be carefully conducted, as the presence of minute greasy particles will always render the colour irregular, and may even entirely prevent its appearance.

A uniform colour can only be obtained by heating the object in such a manner that its temperature is raised evenly throughout.

The tempering may be performed by placing an object on the *blueing tray*, a thin metallic plate often covered with a thick layer of fine brass filings, which should be renewed for each operation; or on a thick piece of metal previously heated to a sufficient degree; on an ignited peat covered with a layer of white ash; in a bath of molten metal, the temperature of which corresponds to the requisite degree of heat, or the object may be laid on the surface of such a

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bath, &c. Some watchmakers when letting down a piece of steel immerse it in water to check the action; but by so doing they produce an exactly contrary effect. If a piece of steel be cooled suddenly in water as soon as it assumes any given colour it will be *softer* than if left to cool in the open air (**78**).

At one of the blue tints steel possesses its *maximum elasticity*. The exact shade varies with the different qualities of steel.

If a hardened and tempered spring have lost its initial elasticity, this may be restored or even improved upon by gently hammer-hardening, and after whitening with emery, again tempering to the proper blue tint.

91. A very convenient way of tempering a large number of small articles at a time, heating them with absolute uniformity, is to place them in a small vessel with sufficient tallow or cold oil to cover them; the whole is then heated to the requisite degree, which may be determined by a thermometer or by observing the smoke. When smoke is first seen to rise, the temper corresponds to No. 2 in the table (article **88**). Smoke more abundant and darker corresponds to No. 5. Black smoke still thicker, No. 7. Oil or tallow takes fire with lighted paper presented to it, No. 9. After this the oil takes fire of itself and continues to burn. If the whole of the oil is allowed to burn away, the lowest temper in the table is reached.

It is often convenient to simply smear an article with oil or tallow, and hold it over a flame or piece of hot iron. The temper can then be judged in the manner just explained.

With a view to combine the two operations of hardening and tempering, M. Caron suggested that the temperature of the water used for hardening be heated to a pre-determined degree. Thus the requisite temper may be given to gun-lock springs by heating the water in which they are hardened to 55° C. (130° F.).

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TO WHITEN AND BLUE STEEL.

92. Some makers of watch hands and balance-springs, when they are not satisfied with the colour assumed by an object in tempering, immerse it in an acid bath, which whitens it, after which the blueing operation is repeated.

We have seen watchmakers whiten small pieces of steel with a piece of pith moistened with dilute sulphuric acid, but the method cannot be recommended.

Others fix fine steel work, a watch hand for example, with wax on a plate, and whiten it by means of pith and polishing rouge, or a small stiff brush charged with the same material. It is then detached by heating, and cleaned in hot alcohol.

These methods, if judiciously employed, are of great service, but it is important to remember always to thoroughly wash after the use of acid, and then to allow the object to remain for a few minutes in alcohol.

Sulphuric acid does not whiten well. It often leaves dark shades on the surface. Hydrochloric acid gives better results.

93. To blue steel uniformly.—In order to secure a uniform colour in tempering or blueing, it is essential that the smoothing and polishing should have been very evenly done; in reference to these points, see **175** and following articles. The surface must be perfectly clean; for otherwise parts that are greasy, or on which the rouge has remained too long, or has been too dry, will not exhibit the same tint as the rest. The heat must be uniformly distributed. This is why, when blueing screws in a perforated blueing pan, it is customary to lightly strike the handle, for the vibration and the perpetual change in the contacts ensures their receiving the heat more evenly. A similar purpose is served by placing the pieces in brass filings. Steel must not be tempered while only in contact with bodies that are bad conductors of heat, stone, either in powder or block, for example; because, as we have already observed,

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the distribution of heat would occur unevenly throughout the metal.

Watchmakers secure a uniform tint more easily by using an iron or copper polisher than one of any other metal.

94. *To blue small steel pieces evenly.* — If the foregoing precautions are carefully observed, the following methods will give satisfactory results :—

First blue the object without any special regard to uniformity of colour. If it proves to be imperfect, take a piece of dead wood that does not crumble too easily, or of clean pith, and whiten the surface with rouge without letting it be too dry. Small pieces thus prepared, if cleaned and blued with care, will assume a very uniform tint.

A clever mechanic assures us that he easily obtains a similar result by rubbing the surface, after it has been well smoothed, with the end of a stick that has been partly burnt in the fire.

95. *To blue a clock hand or a spring.*—To blue a piece of steel that is of some length, a clock hand for example, clockmakers place it either on an ignited peat, with a hole in the centre for the socket, and white over its surface, as this indicates a degree of heat that is approximately uniform, or on a curved blueing tray perforated with holes large enough to admit the socket. The centre will become violet or blue sooner than the rest, and as soon as it assumes the requisite tint, the hand must be removed, holding it with tweezers by the socket, or by the aid of a large-sized arbor passed through it ; the lower side of the hand is then placed on the edge of the peat or blueing tray, and removed by gradually sliding it off towards the point, more or less slowly according to the progress made with the colouring ; with a little practice, the workman will soon be enabled to secure a uniform blue throughout the length, and even, if necessary, to retouch parts that have not assumed a sufficiently deep tint.

Instead of a blueing tray, a small mass of iron, with a

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slightly rounded surface and heated to a suitable temperature, can be employed; but the colour must not form too rapidly, and this is liable to occur if the temperature of the mass is excessive. Nor should this temperature be unevenly distributed.

A spring after being whitened can be blued in the same way. Having fixed one end, it is stretched by a weight attached to the other end, and the hot iron is then passed along it at such a speed that an uniform colour is secured. Of course the hot iron might be fixed and the spring passed over it. A lamp may be used, but its employment involves more attention and dexterity.

96. Blueing as an indication of temper.—This subject has already been very fully considered in articles **88** to **91**. When the colour assumed by a piece of steel does not require to be preserved, and it is only necessary to temper the object at a certain temperature, the means best adapted to expedite the operation will naturally be sought. Thus, in factories, large numbers are tempered at once in a bath of tallow, oil, &c. The workman, in judging temper by colour (**88**), must have enough experience to enable him to determine, for a given sample of steel, what are the successive colours as well as the temperature of the bath, &c. His success is certain; but it depends on the experience, and, therefore, on the sense of sight of the operator, and, we should again add, on the knowledge he possesses of the qualities of the steel he is using.

CASE-HARDENING.

97. This process is often resorted to when a hard surface is required on objects of wrought iron, for example the face of an anvil. It is the exact converse of the method already described in article **59** for obtaining malleable castings, and consists in heating the object to a red heat in contact with charcoal, or some substance containing carbon; this enters

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into the surface iron, converting it into steel. Or after heating to a bright redness the object may be sprinkled over with prussiate of potash, returned to the fire, and after a few minutes cooled by immersion in water. When a greater thickness of steel is needed, or when dealing with large articles, they must be enclosed in wrought-iron boxes, and bedded in such substances as fragments of horn, bones, leather cuttings, &c.; the box is then luted up and the whole maintained at a red heat for twelve hours, after which the fire is allowed to die out. Articles may sometimes be case-hardened by coating with a paste of arsenious acid, powdered leather, horn, or other nitrogenous body and hydrochloric acid, and then heating them to bright redness in a muffle or other suitable furnace.

INFLUENCE OF FOREIGN METALS AND METALLOIDS ON THE QUALITIES OF IRON AND STEEL.

98. It would be impossible to give a full account of this subject in the space at our disposal, and the reader must be referred to works on the metallurgy of iron and steel for details in regard to the remarkable influence of minute traces of phosphorus, tungsten, silicon, manganese, arsenic, &c., on the mechanical and chemical properties of those metals.

COPPER.

99. Copper is an elementary body of a reddish-brown colour which must not be confounded with brass, occasionally termed *yellow* copper. In tenacity it comes next below iron, breaking with a strain of 34 kils. per sq. mm. of section (or 48,000 lbs. per sq. inch).

In horology, the only use made of the pure metal is for the construction of compensation pendulums on the gridiron principle, and as wire in electric clocks. It is also employed, when rolled into thin sheets, for a base to receive the enamel

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of watch dials, in consequence of its expansion being about the same as that of the enamel, which does not therefore crack in the cooling.

The copper of commerce is seldom pure, and this gives rise to many of the imperfections met with in ordinary brass.

ZINC.

100. This is an elementary metallic body of a bluish colour. It is used in the form of rods, for compensation pendulums.

It must be obtained of great purity, whether it is employed by itself or to alloy with another metal. The presence of foreign bodies in zinc, even in very small quantities, has a marked influence on the physical properties of an alloy into which it enters.

The purer the metal the more easily will it roll, and this fact can be taken advantage of as a test of quality.

Although very brittle at 0° C. (32° F.) and 200° C. (400° F.), it has a maximum malleability at about 100° C. (212° F.), the boiling point of water; it should, then, be heated to this degree before bending, rolling, hammering, &c.

It may be annealed in boiling water, or by heating to such a temperature that water hisses when allowed to drop on to it.

It melts at 420° C. (790° F.) and volatilizes if raised to a red heat.

A sudden cooling, or the presence of arsenic or antimony, will render zinc brittle. It must not be melted in cast-iron vessels, as the quality of zinc is deteriorated by the small quantity of iron it takes up under such circumstances.

This metal possesses a great affinity for oxygen, and therefore oxidizes very readily when fused.

It is usual, before pouring zinc that is intended for rolling, to throw some pieces of the solid metal into the

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molten mass, the object being to somewhat reduce the temperature, and thus prevent a too rapid cooling, as, in that case, zinc is very brittle.

BRASS.

101. Pure copper is difficult to work with the graver or file, but such is not the case when this metal is alloyed with zinc; we then obtain *brass*, or, as it is sometimes termed, *yellow* copper.

Alloys containing copper, zinc, and tin are termed *bronzes*.

If a small quantity of lead, about 1 per cent. of its weight, be added to brass, it renders the metal less fibrous, imparting to it a certain degree of brittleness so that it is more easily worked with the graver, file, drill, or the saw.

When the brass is required to be hammered a portion of the lead is replaced by tin; by this means the metal becomes more malleable, or, in terms of the workshop, *soft*.

The colour, tenacity, ductility, malleability, &c., vary with the percentage composition of the alloy. It is, then, of the utmost importance that a watchmaker be able to test and select the brass before employing it in his work; metal that is excellent for wire-drawing, for example, would be utterly useless for making an escape-wheel, since it would become distorted in the cutting in consequence of its ductility. It belongs, in fact, to the class of metals that will extend under the hammer without hardening (very soft brasses).

The following is given as an analysis of brass very frequently employed in horology: copper, 66 per cent.; zinc, 33 per cent.; and lead, 1 per cent. But it must not be forgotten that this is only to be taken as a mean. Both the proportions and the qualities vary with different makers, doubtless also according to the degree of purity of the metals employed in their manufacture.

102. To select brass.—By following the directions

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given below any watchmaker should be able to select the brass best suited to his special requirements.

When the copper is in excess, zinc being proportionately reduced, the brass is usually soft and of a beautiful golden colour. On the other hand, as the proportion of zinc is increased, the brass becomes more and more brittle, and, at the same time, more fusible; the colour changes to a light yellow, ultimately becoming greyish-white, and brass of this nature is said to be "hard."

Very soft brass chokes the file, and spreads without hardening under the hammer; very hard brass, on the other hand, is fragile, liable to crack when hammered cold, and breaks in passing through the draw-plate.

Metal of a good yellow shade, intermediate between the golden and the pale yellow colour, passes well through the draw-plate, spreads out slowly under the hammer, but without cracking, until of about half the initial thickness, and then resists the further action of the hammer, which rebounds from it; such brass is usually found to be of good quality for watchwork.

A sheet of brass is rarely homogeneous. If, after pouring, the metal has been allowed to cool slowly, the interior will be crystalline, and there will be an uneven fracture. This will cause the tenacity, &c., to vary throughout the mass. Similar differences are occasionally to be observed between the two faces of the same plate, due to the phenomenon of *liquation;* that is to say, to a tendency that characterizes certain metals when melted together to separate from one another when the cooling is not effected under proper conditions.

If the two surfaces of a plate be scraped clean at several points and drops, as nearly equal as possible, of very pure watch oil be placed on these clean surfaces, it may be taken as a rough indication that the metals are uniformly distributed if the successive shades of colour of the oil as time goes on are the same at all the points experimented upon.

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Some watchmakers heat the brass to a red heat (which must never be exceeded), and plunge it into nitric acid (equal parts acid and water). By this means the entire surface is cleaned, and the above examination is facilitated.

HAMMER-HARDENING OF BRASS.

103. Plates.—The selection of the metal will depend on the purpose for which it is intended, and the thickness must be such that, when hammered till of sufficient hardness, it will approximately equal one dimension of the required object; for it is advisable to remove as little of the surface metal as possible, a plate always hardening much more at the surface than in the interior.

There is considerable difficulty in indicating clearly in a book the exact mode of conducting the operation of hammer-hardening, and the assistance of a competent master is essential at any rate for the first few trials. It must suffice to point out that the anvil, with a slightly convex surface, and the hammer, of sufficient weight, must be in very good condition and, if possible, polished on their faces; the head of the latter should be rather convex, and the pene or chisel end somewhat broad and gently rounded off in all directions, for it will be needed as a means of bending the metal upwards; the curvature being such that there is not a danger of starting a crack, &c., by its means. We have already spoken of these two tools (**79, 80**); it is only necessary to add that a thick straw pad should be placed under the anvil or block.

When one is compelled to use brass that is too thick, so that there is much work to be done with the hammer to reduce the thickness to what is required, it is a good plan to commence by elongating the metal in one direction, striking with the pene of the hammer a series of parallel blows in the direction of the required elongation; when the thickness is two or three times that ultimately needed, the surface is

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smoothed with the hammer-head and annealed; then it is brought to the right thickness by another hammering in the manner explained below, but it should be again pointed out that, when possible, metal of a suitable thickness ought to be taken in the first instance, since too much hammering has a detrimental effect.

Before hammer-hardening a plate, it must be *dressed*, an operation which consists in rounding off the edges very carefully in order to prevent their cracking, and in rounding the bottom and sides of internal angles which, without such a precaution would occasion a rupture. After this is completed, proceed to the hardening, using a rather heavy hammer, and giving sharp blows along lines parallel to the sides of the plate; commence from one of the corners in the case of a square plate, and with a round plate let the blows be in circles. In the latter case work from the circumference towards the centre, at the same time gradually increasing the force of the blows, since the metal opposes a greater resistance towards the centre. If the work is done evenly and without hurrying, the surface will remain fairly flat, a fact which should be verified from time to time by the aid of a metal rule.

Round plates are sometimes hardened by commencing to hammer in the centre and working towards the circumference along two radii in opposite directions; that is along a diameter. This first diameter is then crossed by another at right angles; the intervals are filled in with other diameters that must not touch until the entire surface is covered, always taking care to work from the centre towards the circumference.

When the metal is thin only the hammer-head is used, but beyond a certain thickness the pene of the hammer must be employed until about half the required thickness is reached; the surface is planished and the hardening finished with the face.

Blows that are irregular, too hard or roughly given, will

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cause the metal to crack. Hurried working will disturb the molecular grouping of the alloy ; it will at the same time be heated and therefore softened, thus losing all the good qualities that are anticipated from hammer-hardening, namely increased body and elasticity. It was in order to avoid this heating that the old watchmakers used to hammer the brass in cold water, an excellent precaution which is too much neglected at the present day.

Brass that is badly hammered, the blows being violent or irregular, will spring out of shape on being cut and occasionally crack when gilding.

If during the progress of hammering, a crack is observed to be commencing at the edge it must be removed with a rat-tail file, all sharp angles being rounded off ; and when cracks immediately reappear on continuing the operation, it is an indication that the metal cannot support any further hammering cold.

If brass is compact or well forged it may be relied upon to preserve the oil at pivots, &c., better, as oil is decomposed more rapidly in presence of a finely divided metal.

104. Brass rods.—Rods having a square section must only be hammered on two opposite faces.

A rod of square section can be hammered on all four faces, but it must be first filed perfectly square, the hammering must not be pushed too far, and the four angles must be maintained right angles. If some are made obtuse and others acute, a flaw will be produced in the direction of a diagonal.

The three following methods are employed in the case of round rods :—

The first consists in hammering over the entire surface, the rod being at the same time rotated on the anvil by hand ; but this operation must not be much prolonged, as the metal is liable to crack lengthwise.

The second method consists in reducing the diameter of an annealed brass rod to about one-half or two-thirds its

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initial amount by causing it to pass in succession through a number of holes of the draw-plate.

When the third method, which is due to Brocot, is adopted, one extremity of the brass rod is gripped in the bench vice and the other end in a hand vice, which is then caused to rotate round the rod as an axis. If the torsion be continued until the metal is on the point of breaking, it will be found to be very effectually hardened. This method is resorted to with advantage for hardening pin-wire and the metal for making pillars.

TO ANNEAL BRASS.

105. When it is necessary to considerably reduce the dimensions of a piece of brass, either with the hammer, rolls or draw-plate, it must be annealed from time to time.

The metal should not be heated to redness; it is supposed, rightly or wrongly, that such a proceeding, especially if repeated, separates a portion of the zinc, or at least changes the mode in which it is associated with the copper. Brass should be heated slowly and uniformly in a moderate fire until the temperature is such that drops of water thrown on to the surface are rapidly converted into vapour, or paper turns yellow and begins to smoke. It is then withdrawn from the fire and allowed to cool.

Brass is brittle when hot, so that it can only be worked cold.

When brass is annealed, just as when steel is tempered, the metal should not be allowed to rest on a bad conductor of heat such as wood or stone, because there will be a tendency to uneven distribution of the heat throughout the metal.

CAST BRASS.

106. This is usually brittle owing to the fact that the copper employed in its manufacture consists, as a rule, of all sorts of scrap from good or bad metal; moreover, from motives of economy, the proportion of zinc is generally

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increased and, in pouring, the precautions essential to avoid the effects of liquation (**102**), &c., are frequently neglected. Such an alloy must never be used for small objects; it must be entirely excluded from a watch, and in a clock only such pivots as are called upon to perform an insignificant amount of work should be allowed to run in it.

In order to avoid injuring the file, or embedding in the metal any particles of the hard coating of oxide that always covers rough castings, it is usual to dip the object in dilute nitric or sulphuric acid (**155**), by which the oxide is dissolved.

TIN.

107. This is an elementary body, almost as white as silver and having a breaking strain of only 8 kilo. per sq. mm. of section (or 11,300 lbs. per sq. inch).

Watchmakers use it in making solder. It is also sometimes used in the form of plates or rods for polishing with rouge, and it is said to be much more efficient when very pure.

If a strip of pure tin is bent, a crackling noise, termed the "crying" of tin, is heard. After frequent bending, the metal loses this property.

The degree of purity may be judged—

(1) By the loudness of the "cry," which is found to be greater as the tin is purer;

(2) By the relative lightness of two balls of equal size, one of which is formed of very pure tin and used as a standard;

(3) By pouring the metal, when just melted, in a mould 1 or 2 centimetres (about $\frac{3}{4}$ inch) in diameter. If tin is pure, when cast into plates or ingots the surface will be perfectly smooth, without exhibiting any signs of crystallization at the moment of solidification, whereas the presence of small quantities of foreign metals causes it to be covered with a network of needle-formed crystals, which are the more numerous according as the metal is less pure.

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The Banca tin is almost chemically pure ; English tin is also very pure ; but others contain a small percentage of copper, lead, iron, or arsenic.

BRONZE.

108. Bronze is an alloy, in very variable proportions, of copper and tin, to which may be added, according to circumstances, a small percentage of lead or zinc, or even iron, when it is desired to increase the hardness or tenacity.

As a rule, this alloy is tough and hard to work : it is especially used for parts of large machines that are subjected to considerable pressure.

The fusion and casting of bronze require special precautions, for the proportion between the metals is liable to vary through oxidation of the tin, which then goes to form a dross, and the composition may vary throughout the mass. It sometimes results from this that the bronze bearings for the pivots in large clocks are not even as good as ordinary brass, and wear away more rapidly than the pivots.

Bronze is also used by watchmakers for making plates or small rods for polishers, and for the bells of clocks. Bell-metal contains about 78 per cent. of copper and 22 per cent. of tin ; it has a beautiful fracture, and is very fusible and sonorous. The addition of any other metal is rather prejudicial than otherwise ; this explains why so many clock bells are wanting in sonorousness.

An impediment to the use of bronze is its want of malleability ; but Dronier has recently pointed out that such alloys may be rendered perfectly ductile and malleable by adding from $\frac{1}{2}$ to 2 per cent. of mercury. These alloys are said to be less oxidisable than ordinary bronzes, and at the same time more hard, elastic, resisting and sonorous.

STERRO.

109. This is an alloy containing 56 per cent. copper, 41

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zinc, 2 tin, and 1 iron. It resembles a reddish-coloured brass, and has been much used in Vienna, where it is considered superior to brass from the point of view of ductility, tenacity and malleability.

An experienced horologist—M. Grossmann, of Glasshütte—has made satisfactory lever escape-wheels of it, and he considers it to be superior to the best brass in regard to both density and elasticity. At the same time he points out that it clogs the cutter, and the colour is inferior to that of good hard brass.

LEAD.

110. A metal with a brilliant bluish-grey lustre, which rapidly becomes dull when exposed to the air. It is very malleable and ductile. It breaks with a strain of 2·9 kilo. per sq. mm. section (4,000 lbs. per sq. inch), but possesses extreme flexibility.

Lead is not used in horology, except as a constituent of solders; in these, however, it plays a very important part. It is occasionally used in the pure state as a lap for applying polishing materials, but more frequently alloyed with tin, by which hardness is imparted to the metal, the alloy being known as "pewter."

NICKEL.

111. An elementary metallic body of a greyish-white colour, resembling that of platinum. With care it can be forged when hot and formed into plates; its structure in that case is fibrous. Its hardness is the same as that of iron, and nickel will take a high polish. Next to iron, it is the most powerfully magnetic of all the metals.

It can be caused to alloy with many other metals—notably iron, cobalt, copper, zinc, tin, and antimony. According to Stodart and Faraday, an alloy of 33 parts iron and 1 part nickel is as malleable as the former metal, but less liable to

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rust. Fleitmann has recently shown that by the addition of about 1-10th per cent. of magnesium, nickel is rendered perfectly malleable and ductile, capable of being drawn into wires or rolled into sheets, and Garnier finds that 3-10ths per cent. of phosphorus has a similar effect.

Nickel is useful as a coating for objects that are not subjected to friction, for preserving them from the action of the air. It takes a beautiful polish, and is not tarnished by being touched.

GERMAN SILVER.

(*Sometimes improperly termed nickel.*)

112. Although the proportion of copper in this alloy is considerably greater than that of nickel, watchmakers frequently apply the latter name to it, doubtless on account of the beautiful polish of which the metal is capable and the comparative inoxidizability which it derives from the presence of nickel.

German silver is an alloy of copper, nickel and zinc, with the occasional admixture of a small proportion of iron or tin. When used in the construction of objects that require soldering 2 per cent. of lead is added.

The alloy usually employed in horology is very malleable; it has a mean composition: copper, 60 per cent.; nickel, 20 per cent.; and zinc, 20 per cent. That containing 58 per cent. copper, 14 nickel, 25 zinc and 3 iron is said to be highly elastic.

The following useful details with regard to the employment of German silver for watchwork are due to M. C. E. Jacot.

Watch movements have been made of this alloy for the past thirty years; it was long thought that the taste would die out, but, on the other hand, the demand for "nickel" movements increases each year.

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The alloy is better prepared at the present day; it has a beautiful greyish-white colour, it is more malleable, and better to work than formerly, but still not so easy as brass. The latter alloy is less detrimental to the file, and can be turned and drilled more rapidly.

German silver is only used for the plates, cocks and bars. The barrels and wheels are of brass, and surfaces exposed to friction, such as the centre pivot-hole (all other holes being jewelled) are bushed with the same metal, for it is observed that in presence of nickel oil is rapidly blackened and the pivots wear sooner than when working in good brass.

The colour remains unaltered for a long time if the surface has been carefully smoothed in the first instance; and if cleansed with soap and water, its original freshness can be to a great extent restored. Some jobbers prefer to employ chemical preparations for cleaning the metal.

The following is recommended as very effective for this purpose:—Mix 50 parts rectified spirits of wine, 1 part sulphuric, and 1 part nitric acid. Allow the pieces to remain in this liquid for 10 or 15 seconds, wash with cold water, and, subsequently, with spirits of wine. Dry with a soft rag or in rotten wood.

GOLD.

113. An elementary body, the most beautiful and the most valuable of all the ordinary metals. In the unalloyed state it has a pure yellow colour, and when reduced to extremely thin leaves, appears green by transmitted light. It is the most malleable and ductile of all the metals, but its tenacity is low.

Gold resembles platinum, silver, iron, &c., in being capable of welding, that is to say, two pieces of the metal can be united without previous fusion. Indeed, by the appli-

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cation of great pressure it can be made to weld when cold.

It is insoluble except in aqua regia (a mixture of 1 part nitric acid and 4 parts hydrochloric acid), alcaline persulphides and selenic acid. Chlorine, phosphorus, and a few other substances can be made to combine with it by the aid of heat.

It is as a preservative, that is applied in layers termed "gilding," that gold is principally used in watchwork, and some details will be found on this subject under "Gilding" (articles **142—153**). Owing to its softness the metal is not used in a pure state, but usually alloyed with copper. The principal alloys in use in this country are :—

22 parts (carats) gold, 2 parts (carats) copper, for coin, wedding rings.

18 parts gold, 6 parts copper, for high-class jewellery, watch-cases.

15 parts gold, 9 parts copper, for ordinary jewellery.

12 parts gold, 12 parts copper ; and 9 parts gold, 15 parts copper, for common jewellery.

The alloys used for soldering gold will be described under "Solders" (**126**).

Alloys of gold with silver and copper have been employed for making watch wheels ; they wear well, and will take a beautiful polish, which is maintained for a longer time than in the case of brass wheels.

Chronometer balance-springs and the suspension-springs for astronomical clocks have also been made of gold-copper or gold-silver alloys rolled and hardened (**666**). If carefully prepared, they maintain their elasticity unimpaired for a long period, and there is no liability to rust.

The dilatation for a given change of temperature is, however, greater than that of steel, so that a greater compensating effect becomes necessary, but this inconvenience is partially compensated for by its inoxidizability and the fact that it is not liable to become magnetic.

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SILVER.

114. This metal in an unalloyed state is too soft for use in horology; its principal use is for cases, and as a constituent of solders.

Houriet made watch wheels of an alloy containing 2 parts silver to 1 part 18-carat gold, and he affirmed that this alloy became polished at the acting surfaces of the teeth. Jurgensen states that detent escape-wheels made of this alloy carefully hammered do not require oil at the points of their teeth.

Dumesnil proposed an alloy of 2 parts copper, 1 part silver, and 1 part zinc, all perfectly pure. Lecocq made chronometer balances in which the brass was replaced by pure silver deposited on the surface of the steel by electrolysis, thus avoiding the use of a fire. The compensation is said to have been very efficient.

ALUMINIUM AND ALUMINIUM BRONZE.

115. Aluminium is an extremely light elementary body, having a density of only 2·56; with equal bulks, therefore, it will weigh only about a quarter as much as silver. As its capacity for heat is very great, this metal is observed to heat or cool more slowly than other metals.

Pure, or in a slightly alloyed state it has not been used in horology except for pendulum rods and large hands in regulator clocks; in short, it can be employed where lightness is the principal quality in view.

It is extremely ductile. The presence of 1-1000th part of bismuth, however, renders the metal somewhat brittle, and it developes cracks under the hammer. Traces of iron also decrease its malleability.

An alloy of 5 parts silver and 95 aluminium can be as easily worked as the pure metal, but is harder and takes a better polish.

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We would add a curious observation of M. Redier :—After passing a piece of aluminium several times through the draw-plate, he observed that the elongation had only occurred at the surface ; for, on cutting the wire at different points, he noticed that, throughout a portion of the length, the metal was hollow, a very fine capillary tube being thus formed.

116. *Aluminium bronze* is an alloy of aluminium with copper. An alloy of 5 parts of the former to 95 of the latter has a beautiful golden colour, but if the proportion is changed to 10 and 90 parts respectively, we obtain the most serviceable and the most easily worked alloy.

This bronze can be forged at a cherry-red heat, and even near its melting point, and its thickness can be reduced to a very small amount under the hammer. It is easily filed and turned, but does not possess any special advantage over brass, which is less detrimental to the file ; the density is 7·7, very little below that of brass, 8·4.

It appears from a considerable number of experiments that it might be used with advantage for the bearings of axes that rotate with high velocities. It resists wear better than any other metal. In the experiments made by Foucault to demonstrate the rotation of the earth by means of the pendulum, he found that an aluminium bronze wire lasted for the longest period. Its tenacity is equal to that of iron. It has been shown that slide-bars of locomotives made of this bronze resist wear twice as long as those formed of the ordinary bronze. There would then be an advantage in using it for the bearings of foot-lathes, &c.

Grossmann asserts that lever escape-wheels of this metal have proved satisfactory, and he makes the following observation on the subject. If aluminium bronze be reduced to 3-4ths of its initial thickness by hammering it will begin to crack. This can be prevented by heating to a red heat and plunging into water ; it can then be again reduced by 1-4th of its thickness, and again annealed, and so on.

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He reduced the thickness from 2·5 millimetre to 0·2 millimetre, and the metal resisted for a long period repeated flexures backwards and forwards; and he observes that no other metal, after being so much compressed, would possess the same marvellous degree of tenacity.

In order to obtain aluminium bronze of the best quality, the copper should be absolutely pure, and, in the manufacture, the alloy must be melted and forged two or three times in succession, as by this means the strength and tenacity are increased, and the metal can be more easily worked.

The beautiful golden colour possessed by certain of these bronzes when polished, has caused them to be used for cheap watch-cases, but they always tarnish at those parts that are not subject to daily wear.

MERCURY.

117. This is the only metal liquid at the ordinary temperature; it solidifies at − 40° C. (− 40° F.). It possesses a high metallic lustre, resembling silver, but with a slightly bluish tint, and does not oxidize at ordinary temperatures.

Mercury alloys with many other metals forming amalgams, and as small a quantity as 1-40th per cent. of lead suffices to entirely alter its character. The presence of such traces can be easily detected by the liquid wetting glass or china, and therefore forming a tail when a vessel containing it is tilted.

The commercial metal is rarely pure, but the greater portion of the lead, tin, bismuth or copper, by which it is contaminated, can be removed by distillation. The most convenient method consists, however, in agitating the metal with either dilute nitric acid, a solution of mercurous nitrate, strong sulphuric acid, a solution of corrosive sublimate or of perchloride of iron, and subsequent washing with distilled water. When mercury is only contaminated with mechanical

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impurities they can be very effectually removed by agitating with powdered loaf sugar.

This metal has many uses in the arts, for the construction of thermometers, barometers, for plating, &c.; in horology it is used for compensation pendulums (see *Treatise on Modern Horology*, pp. 709, 809), and has also been occasionally used for compensation balances.

PLATINUM.

118. This elementary body is almost as white as silver, takes a brilliant polish, and is highly ductile and malleable. It is the heaviest of the ordinary metals, the least expansive when heated, and has a breaking strain of 40 kilo. per sq. mm. section (56,500 lbs. per sq. inch).

Platinum is infusible, except at the high temperatures attainable with the oxy-hydrogen blowpipe. At a white heat, however, it softens, and can be forged and welded. It is unacted upon by the air at any temperature, and is insoluble in acids, except aqua regia (**155**), although acted on by certain alcalis.

This metal is used in the construction of scientific instruments, and for objects that are exposed to the air, as, for example, sun dials. Alloyed with iridium (a rare metal of the same group) it possesses an excellent and unalterable surface for fine engraving, as the scales of astronomical instruments, &c. This alloy has also been adopted for the construction of international standards of length and weight.

Platinum is much employed for chemical apparatus, in consequence of its being unacted on by acids, and its non-liability to melt in ordinary furnaces. Both the pure metal and its alloys with silver have been employed in the form of wire for bushing the pivot-holes of watches, and in sheets for cutting out cocks and wheels, but the results obtained were not as good as with good brass. As a rule, such wheels are found to occasion a rapid wear of pinion leaves.

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Attempts have also been made to construct balance-springs of this metal, but we are informed that they were not found to possess any sufficient advantages.

It is advisable to heat platinum in a spirit-lamp or Bunsen burner; the naked flame is objectionable, because, being charged with a certain amount of carbon, it deteriorates the metal.

PALLADIUM.

119. This metal resembles silver rather than platinum, and is almost as infusible as the latter metal. It has a density of 12·5. When heated in contact with air it becomes blue, owing to the formation of an oxide. It possesses the remarkable power of absorbing (or *occluding*) about 900 times its own volume of hydrogen if attached to the negative pole of a battery in acidulated water; its bulk is increased slightly by this charge, and, on expelling the gas by the aid of heat, the metal shrinks to less than its initial dimensions. Palladium is useful for the graduated scales of scientific instruments, since it is not discoloured by sulphurous acid. It forms alloys with most of the metals, and some of these can be hardened like steel. If 100 parts of steel be alloyed with 1 part of this metal, the resulting alloy is said to be excellent for making scientific instruments, and an alloy of 24 parts palladium, 44 silver, 72 gold, and 92 copper has been recommended for use in horology.

M. Paillard, of Geneva, has introduced balance-springs made of an alloy, whose composition is not given, possessing the following advantages: they are non-magnetic, their tenacity is considerable, are not tarnished by the air, sulphurous acid, or sea-water; nor are they distorted by heating, and, on cooling, they recover their original elasticity, which is equal to that of steel hardened and tempered to a blue colour. The co-efficient of expansion of this alloy is rather less than that of steel.

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CHARACTERISTIC PROPERTIES OF ALLOYS.

120. *Density.*—This is sometimes rather greater and sometimes less than that deduced from the densities of the constituent metals,* but no exact law has been discovered in regard to this question.

Hardness, Ductility, Tenacity.—Alloys are usually harder, more brittle, and less ductile and tenacious than the most ductile and tenacious constituent metal.

Elasticity.—The co-efficient of elasticity of an alloy generally approximates closely to the mean of the co-efficients of its constituent metals.

Expansion.—The co-efficient of linear expansion of an alloy, that is to say, the number representing the proportional part of its length by which it increases for each degree rise of temperature, may be approximately estimated as follows: multiply the linear co-efficient of each constituent metal by the percentage of it present in the alloy, and divide by its density. Add together the several numbers thus obtained, multiply this sum by the density of the alloy (which must be experimentally determined) and divide by 100. The resulting figure is the required linear co-efficient (**122**).

Fusibility.—Alloys are always more fusible than the least fusible of their component metals, and often more so than any one of them.

Oxidation.—As a rule, the air acts with less energy on alloys than on their constituent metals. There are, however, cases in which the converse is the case.

Action of acids.—This is generally similar to the action on the predominating metal.

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* The theoretical density of an alloy, on the assumption that in alloying the metals do not contract or expand, is obtained by dividing the percentage proportion of each constituent metal by its density, adding the products so obtained together, and dividing their sum into 100.

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Observations.—Alloys formed of metals that differ materially in density are rarely homogeneous, especially if they have been allowed to cool slowly. It is, then, essential that they be thoroughly stirred and cooled rapidly. It is for this reason that alloys are frequently poured out on to a flagstone to cool, or that they are compressed after pouring, whereby the formation of crystals is prevented.

121. Metals and alloys.—The following table gives the more important physical properties of the metals and alloys generally met with, and will be found useful for reference. The precise meaning of each number may be gathered from the notes in paragraph **122.**

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METAL.	Specific Gravity. (Water = 1.)	Degree of Hardness.	Linear Expansion per Degree 1° Fahr.	Linear Expansion per Degree 1° Cent.	Specific Heat per Degree Cent.	Melting Point.	Conductivity for Heat.	Conductivity for Electricity.
Aluminium (115)	2·56	—	0·0000123	0·0000222	0·2143	1500°F.	—	56·1
,, Bronze (116)	7·7	—	—	—	—	[about	—	—
Brass, Drawn (101)	8·54	—	0·0000107	0·0000193	0·0939	—	—	—
,, Cast (106)	8·10	—	0·0000104	0·0000187		1870°	—	—
Bronze (108)	8·40	—	0·0000100	0·0000180	—	1692°	—	—
Copper (99)	8·94	2·5—3	0·0000102	0·0000183	0·0951	2000°	73·5	99·8
German Silver (112)	—	—	—	—	—	—	—	7·67
Gold (113)	19·26	2·5—3	0·0000077	0·0000138	0·0324	2160°	53·2	78·4
Iron, Wrought (54)	7·84	4·5	0·0000066	0·0000119	0·1138	2900°	11·9	16·8
,, Cast (58)	6·9 to 7·5	—	0·0000062	0·0000112	0·1298	1920°	—	—
Lead (110)	11·33	1·5	0·0000167	0·0000301	0·0314	608°	8·5	8·3
Mercury (117)	15·60	—	0·000101	0·000182	0·0333	—39°	—	—
Nickel (111)	8·82	5	[cubical	[cubical	0·1086	—	—	13·1
Palladium (119)	11·80	4·5—5	—	—	0·0593	—	6·3	18·4
Platinum (118)	21·50	4—4·5	0·000005	0·000009	0·0324	—	8·4	18·0
Silver (114)	10·57	2·5—3	0·0000111	0·0000199	0·0570	1832°	100·0	100·0
Steel (60)	7·72	6—7 (hard)	0·0000057	0·0000103	0·1175	2400°	—	—
Sterro (109)	—	—	—	—	—	—	—	—
Tin (107)	7·30	2·5—3	0·0000152	0·0000273	0·0569	446°	—	12·4
Zinc (100)	7·13	2	0·0000122	0·0000220	0·0955	680°	—	29·0

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122. Notes on the foregoing table.—For a complete explanation of the several properties of metals and alloys that are enumerated in the above table the reader must be referred to works on mechanics and physics, but the following explanatory notes are necessary.

The number in brackets after the name of each metal, &c., refers to the article in which it is considered.

The *specific gravity* of a substance is the ratio of the weight of a given bulk of that substance to the weight of the same bulk of water at a definite temperature. The numbers here given can only be regarded as approximations, as the specific gravity varies greatly with the state in which a body exists, the hammering it may have been subjected to, &c.

Degree of hardness is ascertained by means of the following standard series, observing which of them scratches the body under examination and which it is capable of scratching.

1. Talc: 2. Gypsum: 3. Calc-spar: 4. Fluor-spar: 5. Apatite: 6. Felspar: 7. Quartz: 8. Topaz: 9. Sapphire: 10. Diamond.

Linear expansion.—These co-efficients represent the extension in length that the several substances undergo when heated: the first column for each degree Fahrenheit and the second for each degree Centigrade. The extension is given per unit of length; thus 1 inch of copper at 32° F. will become $1+0{\cdot}0000102$, or $1{\cdot}0000102$ inch at 33° F., and $1+30 \times 0000102$ or $1{\cdot}000306$ at $32+30$ or 62° F.

Superficial expansion may be obtained by multiplying the linear co-efficient by 2, and cubical expansion by multiplying the same number by 3.

As in the case of specific gravity these data as well as those in succeeding columns can only be regarded as approximations, depending on the condition of the metal, &c.

Specific heat is the amount of heat required to raise the temperature of a substance one degree (the Centigrade scale being here adopted), that required for the same weight of

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water being taken as unity. The corresponding numbers on the Fahrenheit scale can be deduced from those here given by multiplying by 5 and dividing by 9.

The *melting points* are given on Fahrenheit's scale and can only be regarded as approximate on account of the difficulty experienced in determining these high temperatures. Different observers often vary by two or three hundred degrees in their estimates.

Conductivity for heat and electricity are given in reference to that of silver, which is called 100. It surpasses all other known metals in both these properties when chemically pure, but a trace of impurity has a very prejudicial influence on them.

It will be observed that in many cases the conductivities have not been determined, a remark that applies to other columns of the table.

SOLDERING.

123. It is well known that a *solder* is an alloy employed to unite, by the aid of heat, two metallic bodies that are placed in contact. A solder, then, must be much more fusible than the metals it unites, otherwise these latter would be damaged by the degree of heat applied. Solder is all the less tenacious, and melts the more easily, according as the proportion of the most fusible metal present is increased.

This fact is taken advantage of when several solderings have to be performed on the same object. The alloy last employed will require to be considerably more fusible than the first, as otherwise the heat would be so great that the earlier joints would melt. In an ordinary lead-tin solder, the fusibility is increased by increasing the proportion of the latter metal till the lead is to tin, as 6 is to 1. This alloy melts at 194° C. (380° F.), and the melting point may be still further reduced by adding a gradually increasing proportion of bismuth.

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As the melting point of the solder approximates to that of the metals to be united, the risk of damaging these latter is of course increased, but, at the same time, the joint will be all the stronger as the metal will be almost as strong there as at any other point, and it can be forged, &c.

Solders are distinguished as *hard* or *soft;* the former require the application of a red heat, and can therefore only be used for such metals as gold, silver, brass; whereas the latter melt at very low temperatures, and can be employed for metals that have low melting points, or when it is important not to exceed a moderate degree of heat. The joint is, however, the more solid according as the heat employed approximates to that at which the metal will melt.

124. Composition of solders.—The solders ordinarily employed can be obtained at tool-shops, but it is advisable to give here the composition of some of the more important, specifying the metal to which they are applicable.

125. *Aluminium solders.*—I. Zinc, 70 parts; copper, 15; aluminium, 15.

II. M. Mourey employs a series of aluminium-zinc alloys, commencing with 2 per cent. aluminium to 98 per cent. zinc, and progressing to 20 per cent. of the former to 80 per cent. of the latter metal.

126. *Gold solders.*—I. Gold, 6 parts; copper, 1 part; silver, 2 parts.

II. Gold, 15 parts; silver, 2 parts; copper, 1 part.

III. Gold, 11·94 parts; silver, 54·74 parts; copper, 28·17 parts; zinc, 5·81 parts. The three first metals are melted together in a crucible, and when they have somewhat cooled, a rather greater proportion of zinc than is here indicated (to allow for loss by volatilization) is added, and the alloy constantly stirred.

127. *Silver solders.*—I. Silver, 2 parts; brass (for pin-wire), 1 part.

II. Silver, 5 parts; pin-wire brass, 1 part.

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III. Silver, 10 parts; pin-wire brass, 5 parts; pure zinc, 1 part.

128. *Tin solders.*—I. (Ordinary soft solder.) Tin, 2 parts; lead, 1 part.

II. (Harder, and known as "Plumbers' Sealed" solder.) Tin, 1 part; lead, 2 parts.

III. Many other proportions of tin and lead are occasionally used, ranging from tin, 1 part; lead, 25 parts, to tin, 6 parts; lead, 1 part.

IV. (Very fusible solder, melting in boiling water.) Lead, 3 parts; tin, 5 parts; bismuth, 8 parts. The fusibility is still further increased by adding mercury or cadmium.

129. *Spelter solders.*—(Used for brazing.) Copper and zinc in varying proportions. It becomes more fusible as the amount of zinc present is increased.

METHODS OF SOLDERING.

130. A thorough cleansing of the surfaces to be united is always needful, but more especially so in the case of soft soldering. It may be effected by means of acids or with a graver or scraper, &c.; the cleaned surfaces must not be touched with the fingers, and the soldering should be done at once. If acids are employed, the objects should be thoroughly washed after soldering, in order to avoid rust; and, after drying, they should be rinsed with alcohol.

The parts to be soldered are held in position with clamps, tweezers, pins, or iron wire. This latter, known as *binding wire*, is used for delicate objects and should be very pliable. When a high degree of heat is to be applied, all risk of the iron uniting with gold may be avoided by mixing a little sandiver with the borax employed. (See article **153**.)

Before heating, if there are already parts united with solder, they should be covered with borax to prevent softening.

Only a moderate heat should at first be applied, so as to

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melt the borax or sal-ammoniac without displacing it. The violent frothing up, which is very liable to displace the parts or the fragments of solder, can thus in great part be avoided. If a naked lamp-flame is used, or if it is directed on to the object with a blow-pipe, it should be, so to speak, large and soft, and the jet should not be directed to the point of juncture until the solder is observed to have fused. In soldering brass to steel, it is sometimes necessary to direct the flame against the brass only, in order, as far as possible, to avoid softening the steel. The hard solders for gold, silver, &c., require a considerable degree of heat, so that the objects must be heated to redness.

131. To solder gold and platinum to each other or to themselves.—On a hard wetted surface, marble, for example, rub a piece of borax until a white liquid paste is obtained (or the powdered borax sold by chemists can be made into paste direct). Having prepared the borax, the surfaces to be united are cleansed either by scraping or with dilute nitric acid (**155**); the acid may be previously heated to boiling as it will then act more rapidly; and the surfaces are subsequently scraped. They are now covered with the borax with a paint brush, set in position, and small pieces of solder placed on the junction. As already observed, the heating must at first be gentle to avoid displacing the solder by the frothing of the borax.

132. To solder silver.—Also for uniting gold to silver, or silver, brass, steel to each other or to themselves. —Proceed in the manner already explained for gold and platinum, except that the borax paste must be sensibly thicker.

133. To solder tin.—Also for uniting gold, silver, brass to each other or to other metals, such as steel, iron, &c. —Clean the surface with a graver or scraper; sulphuric or hydrochloric acid may be used, but in this case the cleansing afterwards must not be forgotten.

The heating is effected as in soldering gold, unless a

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soldering iron is used, when the directions subsequently given should be followed.

134. To solder aluminium.—M. Mourey recommends the following method :—

One of the series of aluminium solders, No. II. (art. **125**), is employed and, as a flux, two-thirds of balsam of copaiba, one-third very pure Venice turpentine, and a few drops of the juice of a citron ; these constituents are pounded together in order to secure a perfect admixture.

The surfaces to be united are covered with solder (employing a soldering iron of aluminium) just as in the case of tinning (**137**), the flux just mentioned being used. The two surfaces, thus prepared, are placed in contact and maintained in the required position, and, after laying on the joint particles of solder that are richer in aluminium than the one used for preparing the surfaces, the whole is placed over a charcoal fire or heated before the blow-pipe, pressing gently on the pieces of solder, which will soon melt and should be distributed by means of a little tool of aluminium.

During this second stage of the process, it is necessary to be very cautious in the application of the flux; the pieces of solder should only be dipped in it before being placed in position, for the flux is mainly for use in preparing the surfaces ; as soon as the solder has run well, the temperature should be lowered in order not to dry up and burn the solder, which would be apt to become brittle.

In preparing the solders, the aluminium is first fused and stirred with a small iron rod ; then add the zinc and stir again ; add a little tallow and cast the solder into rods.

The zinc must not be too much heated, as it will volatilize, leaving the alloy rich in aluminium and therefore brittle.

135. Fluxes for soldering.—Various substances can be employed as fluxes for cleansing the surfaces to be united :—

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Sal-ammoniac reduced to powder and made into a paste with sweet oil, or merely dissolved in water.—A paste formed of *sal-ammoniac* and *resin*, reduced to powder, with water or oil.—*Resin* alone will suffice for the soft soldering of copper or brass.—*Venice turpentine*, which has the advantage of not causing steel to rust, although it makes the objects sticky so that they require to be afterwards rinsed in alcohol or turpentine.

Various acid solutions are sold for the purpose and experience will enable the watchmaker to select that which is best adapted to his requirements.

Lastly, saturated *chloride of zinc* can be recommended. It is prepared as follows :—

Some dilute *hydrochloric acid* (which also goes by the name of spirits of salts, or muriatic acid) is placed in a glass flask and strips of zinc are added one by one ; the flask must be left uncorked and the zinc added a little at a time, lest the effervescence that occurs should break the vessel. When the zinc added is not acted on by the fluid it may be concluded that the acid is saturated or "killed." and the fluid may then be transferred to a stoppered or corked bottle for use. In using it a small quantity is spread over the surfaces that are to be united and the solder will be found to run with great freedom (some authorities recommend the addition of sal-ammoniac to the extent of one-fourth the weight of acid taken). It is well again to warn the reader that the pieces must be thoroughly washed after employing these liquids, for, otherwise, they will cause tools with which they are brought in contact to rust and will rust themselves if they consist wholly or in part of iron or steel. The vessel containing the fluid must be kept well away from the work-bench.

The liquid can be used immediately after being prepared as above explained ; but all acid reaction may be prevented by evaporating at a moderate temperature until of the consistency of oil ; it is then allowed to cool and kept in a bottle.

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136. The soldering iron with a head of copper, such as is used by tin-plate workers, is well known; if made on a small scale it may occasionally be of service to the watchmaker. The tool may be T-shaped, one end of the horizontal portion, the copper head, terminating in a rather thin blade and the other enlarged, so that, when held in the flame of a lamp, it will store up a sufficient amount of heat. The upright part of the T corresponds, of course, to the handle. After the iron has been heated just short of redness in the dark, the end of the blade is moistened with soldering fluid and a small piece of solder attached to it. The object to be united is gently heated and also moistened with the fluid; the iron charged with solder is presented to it, often with the enlarged extremity of the head maintained in the flame of a lamp, and the solder will, as a rule, run without again heating the object, although this might be done while the iron is still in contact. It may be found convenient to fix the iron in a suitable position with the lamp below the large end of the head; the object will then be brought against the iron after being moistened with the fluid.

137. It is often advisable to *tin* the surfaces to be united previous to soldering them; in order to do this they are moistened with soldering fluid, small pieces of solder are then spread over, and these are fused by passing the hot iron over the surface; or the solder can be spread after fusion by means of a metallic rod charged with the liquid.

138. Brazing.—This operation consists in soldering iron, steel, brass, or copper, with an easily fusible brass, which is specially prepared in the form of coarse dust, termed spelter solder, or cut in thin strips of convenient shape (**129**). The method resembles, in all essential particulars the application of hard solders previously referred to (**131**, &c.).

Heat is usually applied direct by the blow-pipe, borax being used as a flux, and the precautions taken that are mentioned in article **130**: it is necessary to avoid a

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greater degree of heat than would melt the brass, since the object might in that case be fused. For fine work, it is better to employ silver solder.

On an emergency, two pieces of steel can be united by brazing and subsequently hardened, and we have successfully practised this method in such a case as the following :— A small portion having been broken off from the quarter-piece of a repeater, we dovetailed into it another piece of steel of the required form, but a trifle too large at the upper side. When the brass had run well into the joint, and the piece was still at a full cherry-red heat, it was hardened, and afterwards cleaned and tempered to a blue colour. The upper surface was then brought to shape with a good file, resting it on a wooden block against a projection, and, after making sure that it would act correctly, the whole was smoothed and polished. It has since worked well and does not show signs of wear.

BRONZING.

139. To bronze copper. — The following are two methods recommended for bronzing objects of this metal, for example, a medal.

Dissolve two parts of verdigris (acetate of copper) and one part of sal-ammoniac in vinegar. Boil the solution, skim it, and dilute with water until it no longer possesses a feebly metallic smell, nor produces a whitish precipitate on the addition of water. Then let it boil again in an earthenware or porcelain vessel and transfer it, while boiling, into another vessel containing the perfectly clean medals, &c., and place the whole on the fire. As soon as the medals assume the required colour, remove them, and wash carefully in clean water.

The objects must not be left too long in the acid bath over the fire, because the layer of oxide would become too thick, and would easily scale off the surface ; whereas, if the

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operation is properly conducted, the coating adheres so firmly that it cannot be separated even by scraping. Of course, it is only after a certain number of trials and with experience that the exact moment can be ascertained for removing the objects from the bath.

It is very necessary that the bath be not too concentrated, as the superficial oxide becomes proportionately less adherent: moreover, a whitish powder is deposited on the medal, which turns green on exposure to the air and spoils the appearance of the bronzing.

140. Chinese bronzing.—The Chinese employ the following mixture for bronzing copper, the several constituents being powdered before being incorporated together: 2 parts of verdigris, 2 parts of cinnabar, 5 of sal-ammoniac, 5 of alum, and 2 parts of the beak and of the liver of a duck. A paste having been made, with vinegar, it is spread over the perfectly clean surface of the copper, and the whole exposed for an instant to the fire, then allowed to cool, washed, and the operation repeated as often as may be needed in order to obtain the desired tint.

By adding sulphate of copper to the mixture a browner shade will be obtained, and it may be made yellower by adding borax. Copper thus treated is said to present a beautiful appearance, and to be so permanent that neither air nor water has any influence against it.

141. To bronze brass.—Dissolve copper turnings in nitric acid until it is completely saturated. Immerse the brass objects to be bronzed in this solution after they have been cleaned, smoothed with water of Ayr stone, and heated to such a temperature as the hand can just support; on being placed over a charcoal fire they will assume a green colour; rub them over with rags, repeat the immersion and heating over charcoal until the required tint is obtained. The shade may be improved by oiling the finished surfaces.

It is asserted that by immersing copper articles in molten sulphur containing lamp-black in suspension, they assume

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the appearance of bronze; and that they may even be polished without losing their colour.

GILDING.

142. Cold gilding without the aid of mercury.—Prepare the gold in fine powder, as explained in the following paragraph, or procure it from the dealers in chemical products, who manufacture it of various tints. Make a mixture of this powder with pure rock salt and cream of tartar (bitartrate of potash), pulverized in the same manner as described in speaking of silver-plating (**692**), and take the same precautions in its application.

The gold surface will present a dull appearance; acid cannot be used to improve its colour when operating, for example, on a wheel with attached pinion, but the same result may be attained by a very simple method. Rub the object after plating with cream of tartar, mixed with a large proportion of water; then immediately wash in an abundance of warm water at not less than 40° C. (104° F.); soap it thoroughly so as to neutralize any acid that may remain, and finally pass through alcohol to dissolve any remaining soap.

The surface will be still further improved by rubbing with a very hard piece of pith, such as is occasionally met with.

M. Robert, in describing the above method, adds:—"In this manner I have gilded cocks, domes, compensation balance weights, and even their brass rims. When skilfully and expeditiously performed, the pinion need not be discoloured; but, if it is at any time slightly marked, it may be restored by at once rubbing the surface with a soft stick and fine rouge."

143. *Preparation of the gold powder.*—As already observed, this can be obtained of any desired colour from the dealers in chemical products, but the following method is given for the benefit of any one who desires to prepare it for himself:—

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Place some gold in thin leaves in a dish, and add a little honey, thoroughly intermixing the two by the aid of a glass rod flattened at one end; then place the paste so obtained in a glass of water containing a little alcohol, washing it and allowing the powder to settle. Decant the liquid and again wash the residue, repeating the operation until a fine brilliant powder is obtained. This powder is mixed as required with rock salt and powdered cream of tartar in the manner already described.

144. *Second method.*—Dissolve one part by weight (say about 10 grains) of pure gold, rolled very thin, in aqua regia (**155**) contained in a porcelain dish, which may be gently heated on a sand-bath, and evaporate the acid until it assumes a blood-red colour. Add about 30 parts, by weight, of warm distilled water, in which 4 parts of crystallized cyanide of potassium have been previously dissolved; thoroughly stir the mixture with a glass rod, and filter it through a glass funnel.

145. *Third method.*—Roseleur recommends the following solution for gilding by simple immersion. Distilled water, 17 pints; pyrophosphate of soda (in crystals), 28 ounces; hydrocyanic acid, $\frac{1}{3}$ ounce; crystallized perchloride of gold, $\frac{2}{3}$ ounce. The pyrophosphate is added, in small quantities at a time, to 16 pints of water, in a porcelain vessel, stirring with a glass rod and applying gentle heat; then filter and cool. The gold salt is dissolved in a small amount of water, filter and add to the cold solution of pyrophosphate; lastly, add the hydrocyanic acid and the solution, heated to the boiling point, is ready for use.

The articles to be dipped must be thoroughly cleansed and passed through a very dilute solution of nitrate of binoxide of mercury: they must be constantly agitated while in the bath and the best coating is obtained by dipping the articles in a nearly exhausted solution of the same kind immediately after the mercury solution.

146. Electro-gilding.—But the method most usually

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adopted is that in which a battery is employed. It is, however, impossible, within the limits of this work, to explain the precautions that are necessary in conducting the process, managing the battery, &c., and the reader must be referred to works on electro-metallurgy* for these details.

147. To prepare the pieces to be plated.—After the surface has been stoned, boil the object for a few minutes in a solution of soda or potash, and rinse in clean water.

Roseleur, in the articles already referred to, gives very full instructions, of which the following is an outline. The reader who desires to obtain more complete information can consult the works mentioned below.

Attach the pieces to a cork and brush with a clean brush charged with water and pumice-stone powder and thoroughly rinse. Place them in a solution consisting of: water, $2\frac{1}{4}$ gal.; nitrate of binoxide of mercury, $\frac{1}{14}$ oz.; sulphuric acid, $\frac{1}{7}$ oz. Then rinse again.

148. Graining.—Mix thoroughly, with the application of a moderate heat, silver powder (**690**), 1 ounce; pure common salt, finely powdered, 13 ounces; cream of tartar, 4 to 5 ounces. Make a thin paste of this mixture with water and spread with a spatula on the pieces: having mounted them on a cork to which a rotatory motion is given, rub them in all directions with a brush with close bristles, adding fresh paste from time to time. When the desired grain is obtained, wash and scratch-brush with revolving wire brushes. Three of these are often used of varying degrees of hardness and a decoction of liquorice, weak size or stale beer is liberally applied to the surface.

149. Resist.—This is a composition for covering steel parts in order to protect them from the action of the acids, &c.,

* Gore: "The art of electro-metallurgy" (Longmans); A. Watts: "Electro-metallurgy practically considered" (Crosby, Lockwood and Co.); J. Napier: "Electro-metallurgy;" Roseleur: "Practical Instructions to Electroplaters, &c.," in Vols. VI. and VII. of *The Watchmaker, Jeweller and Silversmith.*

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in the various processes of cleaning, graining and gilding. It consists of yellow wax, 2 ounces; clear resin, 3½ ounces; very fine red sealing-wax, 1½ ounces; finest rouge, 1 ounce. Melt the resin and sealing-wax in a porcelain dish, then add the yellow wax, and, when the whole is thoroughly liquid, gradually add the rouge, stirring with a glass rod. The parts to be coated are slightly heated and covered with the mixture.

To remove the resist after the gilding process is completed place the pieces in warm oil or turpentine, then in a very hot soapy or alkaline solution and lastly in fresh water.

150. When prepared as above explained the object may be gilt by one of the preceding methods: of course a hot solution cannot be resorted to when the resist has been applied.

Some further information more especially referring to watch dials will be found in articles **694—5**; the articles on silvering dials (**680—693**) may also be consulted with advantage.

151. To clean objects that are of gold or gilt.—The following method is equally applicable to pieces that are gilt, such as cocks, domes, &c., the frames and parts of time-pieces and to either gold or gilt jewellery.

To about a tumbler of water add 20 drops of strong ammonia. Immerse the object several times in this mixture and brush it with a soft brush; as soon as the operation appears to be completed (which experience will soon enable the workman to ascertain), wash in pure water, then in alcohol, and dry with a fine linen rag. The original brilliancy of the gilding will then be restored.

When the coating is thin and has been galvanically deposited only very soft brushes must be used.

Gilders instead of dipping in alcohol and drying with a linen rag usually immerse the pieces in fine wood sawdust, leaving them long enough to become thoroughly dry: after this treatment they merely require to be shaken and lightly rubbed with a fine brush.

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The sawdust must be perfectly dry; indeed it is a good plan to slightly warm it by placing the wooden box containing it for a few minutes on a hot oven or stove in the winter and exposing it to a hot sun in the summer.

Instead of ammonia, alum (**156**) is sometimes boiled in water and the objects dipped two or three times in this solution, subsequently brushing as in the previous case.

152. *To restore the dead surface of gold or gilt objects.*—Place them for two or three minutes in chlorine water, rinse in clean water, soap them and finally dry in sawdust. It is advisable that parts that are polished be prevented from actual contact with the liquid as it would produced a somewhat deadened surface.

153. *To clean gold jewellery after soldering.*—Particles of binding wire are often left adhering to the surface of jewellery after soldering, and, on dipping the object into the dipping liquid, a layer of oxide may be formed. This can be removed without detriment to the polished surfaces by plunging the object for a few seconds in nitric acid (**155**).

ACIDS AND SALTS.

154. The watchmaker has occasion to employ a few acids and salts. He should never forget the advice already given to keep them away from his work-bench, and always to well wash a piece of metal that has been in contact with them.

155. Acids.—*Nitric acid,* either in a concentrated or dilute form, will dissolve iron, steel, copper, lead, silver, zinc, brass, nickel, mercury, German silver. It does not dissolve tin, but reduces it to a white powder, known as metastannic acid. Hence if an attempt be made to dissolve bronze, which contains tin, this metal is deposited, and the copper and zinc pass into solution.

Sulphuric acid will dissolve iron, steel, copper, tin, silver, zinc, brass, nickel, mercury, German silver.

Hydrochloric acid will dissolve iron, steel, copper (slowly),

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tin (slowly), zinc, brass (slowly), nickel, German silver (slowly).

Aqua regia, a mixture of about 2 parts hydrochloric and 1 part nitric acid will dissolve all the above-named metals, and in addition, gold and platinum although, separately, neither acid will attack these metals.

Hydrofluoric acid attacks and dissolves all metals except platinum, lead, and silver with violent effervescence. It is also used for etching on glass or enamel. It is usually preserved in gutta-percha bottles, and is of such a dangerous nature that no use should be made of it without a good knowledge of its properties.

Acids are rarely employed pure by watchmakers; they are diluted with water. Nitric acid of commerce has a density of about 1·4 (38° on Baumé's hydrometer). If this density is reduced by the addition of water, to 1·16 (20° Baumé), we obtain the acid most commonly employed. For cleaning metallic surfaces prior to soldering, &c.; for giving a grained surface to brass, and for whitening blue steel, special proportions are found most convenient which the reader can best determine experimentally for himself, remembering that the action of the acid should neither be too quick nor too slow. When once he has ascertained the best proportion, he can always recover it by the aid of the hydrometer.

156. Salts.—*Borax* serves as a flux in soldering gold, silver, platinum, &c. (**131**); also for the same purpose in brazing (**138**); it is met with in crystals or as a powder.

Sal-ammoniac (also called *chloride of ammonium*) is used for soldering tin, either as a powder or made into a paste with sweet oil or with water, or mixed with resin.

Alum dissolved in water may occasionally be used in place of nitric acid for cleaning surfaces that have been soldered; it attacks iron and steel more energetically than copper, zinc, or brass. This fact is often taken advantage of for removing broken screws, &c., from brass plates. All other

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steel parts are removed and the plate placed in a solution of alum, when the steel screw is gradually eaten away by being converted into rust. (See **370.**)

In 100 parts of cold water only 9 parts of alum will dissolve, but if the water be boiled it will take up 75 parts. Its action will then be proportionately more energetic when boiling.

OIL.

157. The oil intended for use as a lubricant for watch-work, &c., should be kept away from the light, as otherwise it would be discoloured; it is on this account that the bottles containing such oil are frequently covered with black paper. Only the quantity wanted for immediate use should be placed in the oil-cup.

Two preliminary tests will afford some indication as to the quality of an oil. A thick layer is placed on a small portion of the surface of a glass plate, and side by side a similar layer of another oil used for comparison, and they are exposed to the air for some time without being touched. The one that is found to be sticky under the finger when the other has dried up will in all probability be preferable. The second preliminary test is made on a whetstone; it is usually found that the oil that takes the longest time to thicken is of better quality. Of course these tests will only suffice to afford a rough approximation, and cannot be accepted as conclusive.

The mode adopted for testing either the acidity or the purity of oil will afford no evidence as to how long it will maintain its fluidity; and very good results have at times been secured by the use of oils that were slightly acid, or from mixtures of oils of two or more qualities.

Many of the methods recommended for purifying oils are to a great extent illusory, for they cannot impart to the fluid characteristics that are wanting from the beginning.

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Success depends largely on the skill of the manipulator; and if he is not endowed with the power of judging, mainly by the taste, whether oil satisfies certain prescribed conditions, he can never be certain of the result. Crops differ as regards degree of maturity, &c., from year to year; and the animals from which oils are procured are rarely in the same condition as regards health, age, nourishment, &c.

Tests made on a whetstone and on a window-pane, as well as observations made on drops of oil placed in jewel-holes, or in oil-cups in a metal plate kept for the purpose—some of the drops being exposed to the air, while others are in closed boxes—will afford valuable indications; and, according to the observations of M. H. Robert, it is safe to consider an oil bad if, at the end of six or eight days after being placed on a plate of good brass, it shows a marked green tinge—especially so if a clearly-defined fringe forms round the drop, or else if the brass itself is discoloured.

After all, the only evidence on which the watchmaker can rely is that which he obtains by experimenting on watches which he keeps to lend to his customers while their own are undergoing repair, and these trials should last for at least a year.

And there is great variety among the wearers of watches. Some live in constantly-varying temperatures, often dusty; many ladies use perfumes; some persons perspire more than others: all these causes influence the oil, and make it alter or evaporate more rapidly in one watch than in another.

158. To secure the maximum permanency in oil.—In the case of very many watchmakers who complain bitterly of the oils they employ, the fault is their own and not that of the oil; for they neglect the most simple precautions both in purchasing and in using it.

The following are a few points to which attention should be given:—

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Do not buy, from motives of economy, bottles that have lain for years in the shop.

Keep the oil away from the light, and only take in the oil-cup the amount required for immediate use, as stated above.

Ascertain that the watch-cases close well. If they do not, there will be air-currents generated, and the oil will suffer.

The oil in a cylinder escapement will always deteriorate very rapidly; some watchmakers coat over the inside of the dome-joint and recommend the owner not to open it. By doing so, the oil can be maintained in good condition at the escapement for a long time.

Lastly, when cleaning a watch, the work should be conscienciously done. This point is very important.

When the parts are carelessly cleaned with soap or with impure benzine, they will, after a few months, assume a dull colour, in consequence of a thin layer of the materials used in cleaning having been left on the surface. It has at times been noticed that steel work was preserved from rust through the perspiration of the wearer, after being cleaned by certain fluids. Evidently this was due to a thin coating having been left on the surface of the metal. The conclusion to be drawn is obvious: clean carefully, push the pivots into rather hard pith, finish with a soft brush in proper condition, and clear out all pivot-holes with pegwood.

159. Mixed oils: camphorated oils.—Good results are frequently obtained by mixing together two different kinds of oil. Thus, American watch oil, which is very fluid and apt to evaporate at the temperature of the pocket, is improved by the addition of a somewhat thicker oil. A mixture of real American oil with the Rodanet oil has been recommended as excellent.*

* Although no results have been published on the question, it seems probable that some of the modern mineral lubricating oils might be added with advantage in small quantities to the ordinary oils. (See *Hor. Journ.*, xxiii. (1881), p. 101.)

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There are some who advocate the addition of a small quantity of camphor to an oil that is known to be satisfactory, but we cannot answer for it from personal experience.

160. Sinks.—In cleaning it is important to avoid removing the gilding in the oil-sinks of watches or the superficial oxide in the sinks of clocks that have been going for a considerable time. For if it be removed, there will be a fresh coating formed in time, and this, too, at the expense of the oil.

In new timepieces that are not gilt it is well worth while polishing the sinks over their entire surface. If not applied too liberally, the oil will then be more likely to remain in contact with the end of the pivot. Moreover, as the surface is smoothed and hardened and its pores are, as it were, closed by the action of the polisher, the oil will oxidize more slowly. This fact was first pointed out by Robin.

161. *Caution to be observed in applying oil.*—The precautions to be observed in applying oil will be better considered in Part V. of this work, where we shall describe the method of cleaning and putting a watch together (see articles **530—3**).

162. Retention of oil on acting surfaces.—Since oil is essential in order to diminish friction, and the movement of the bodies to which it is applied tends to drive it from the surfaces of contact, it is important, with a view to its being constantly brought back and maintained in proximity to these surfaces, that they be formed in accordance with certain rules based on the laws of hydrostatics. We cannot, however, enter on this subject here, but would refer the reader to pp. 35 to 40 of the *Treatise on Modern Horology*, where he will find it discussed.

ALCOHOL.

163.—Only what is known as rectified alcohol should be used in cleaning parts of watchwork. The copper pan in

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which it is made to boil should not be too thin. The handle should be so arranged that it can be fixed in the vice, and the lamp held under the pan.

When, in heating, the alcohol ignites, it is best not to attempt its extinction by blowing ; if the pan is held against the under side of the bench the flame will at once be put out, or this can be effected by merely laying a piece of sheet metal over the pan. A good plan for preventing ignition, is to make a lid of wire gauze, which is placed over the pan during the application of heat.

The substance known as "methylated spirit" is a cheap preparation of alcohol, and of use for burning in a spirit lamp, and for other purposes where the alcohol is not required to be pure.

BENZINE, ETC.

164. This and other preparations of a similar nature, such as Essence Lemoine, Essence Genevoise, &c., are much used for dissolving clogged oil and other substances of a greasy nature from parts of watches in cleaning. Notes in regard to their use will be found in article **525**.

POLISHING MATERIALS.

165. The following account of the materials used for polishing, is, for the most part, extracted from Holtzapffel's *Turning and Mechanical Manipulation*, to which the reader is referred for fuller information in regard to them, and to their mode of application :—

Buff leather, glued to a flat surface, or to the edge of a revolving disc, is used with emery, crocus, rottenstone, and other powders.

Charcoal is much used by steel and copperplate engravers. That made by burning elder without access of air is considered the best, but willow and elm have also been recommended.

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Diamond, in the form of powder, is used by lapidaries, seal engravers, and watch-jewel makers. The latter obtain the diamond *bort* that is rubbed off stones in facetting, and they separate it into various degrees of fineness, by decantation (**169**). The mode of applying it is described in articles **207—216.**

Diamantine, Sapphirine, Rubitine, &c., are names given to various chemical preparations for polishing to be obtained at the tool-shops; they must not be assumed to consist in any way of the jewels from which their names are derived.

Emery.—At the present day, oilstone dust is very frequently replaced by emery with oil or water, especially in clockwork. Any required degree of fineness can be obtained by decantation. Emery dust is sometimes used in place of rouge for polishing.

The solid emery wheels and sticks, that are now common in the trade, work rapidly, but they have the disadvantage of heating steel, and many of them soon become pasty. The heating renders them less suitable for grinding gravers, but they are very convenient for roughly shaping steel work, or removing the hard surface caused by the application of heat.

To make emery paper.—If occasion requires it, this can be done as follows:—Fix a sheet of stout blotting paper on a board, glueing it round the edge. Having put emery powder into a sifter, the mesh of which has the requisite degree of fineness, and rapidly covered the surface of the paper with thin hot glue, shake the sifter lightly over the paper until it is evenly covered, and leave to cool. When dry, detach the paper and shake it vigorously to detach loose grains.

Hone slates.—Under this heading are included a great variety of stones used for smoothing and polishing.

Ayr-stone or water of Ayr stone is much used for smoothing brass work prior to gilding (**142**), &c.; it should be kept wet in order to prevent it from becoming hard.

Blue polishing stone is much used by jewellers, clock-

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makers, and others ; it is recommended for use in spotting (**174**) and for polishing wheels (**176**).

Oilstone.—This forms the quickest cutting whetstone known. Oilstone slips are used by watchmakers after the manner of files. Oilstone powder or dust is much used in the earlier stages of polishing, and is preferable to emery in that it does not leave particles embedded in the surface of the metal. On pewter laps it may also be employed for polishing steel work.

Oxides of iron.—Under this head are included the several materials known as crocus, rouge, red-stuff, colcothar of vitriol, &c. It is advisable to remove gritty particles from these materials before using by decantation (**168**).

Pumice stone is extensively used for polishing cut-glass, and is applicable to brass and other metal work.

Putty powder is oxide of tin, or, more commonly, of tin and lead in varying proportions. The whitest kind, provided it be heavy, is considered the best.

Rotlenstone.—This variety of tripoli, which is met with in Derbyshire, is of the greatest value for polishing brass work, as well as for silver, glass, and even the hardest stones.

Tripoli is of a greyish yellow or red colour, and consists mainly of silica. Its principal use is in the polishing of hard woods.

Whiting is common chalk, ground, washed to remove sand, &c., and dried in lumps.

166. Polishing Stones.—The following method is described by M. Cadot for preparing these stones, which are very useful for polishing a wheel that is not riveted to its pinion (see article **185**).

Carefully select a blue stone ; after dressing its surface, smooth it with emery paper of gradually increasing fineness. Saturate the surface with oil, and rub it with a common piece of rough sapphire, one face of which is flat and partly smoothed, until the surface of the stone is hardened.

Such a stone is used dry. The wheels must previously

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have been carefully smoothed, since the stone does not abrade the metal. If care is taken to avoid scratches, the surface will last for a long time, although, of course, it is only serviceable for gold, brass, nickel or metals of a similar degree of hardness.

167. The several materials used for polishing must be kept carefully packed (glass-stoppered bottles are preferable), as a few grains of dust or of foreign bodies will suffice to prevent the operation of polishing from being successful. Polishers should be filed very smooth with a perfectly clean file that is not quite new. Files that are dirty or new will deposit small hard particles of dirt or cause pieces off the points of their teeth to become embedded in the surface of the polisher.

PREPARATION OF POLISHING MATERIALS.

168. Decantation.—This consists in causing a material in a fine state of sub-division to fall slowly through a liquid with the view to separate coarse particles or various degrees of fineness by taking advantage of their different rates of descent.

The watchmaker should prepare all his smoothing and polishing materials, &c., by decantation. He will by this means obtain them in grains that are much more uniform in size, of any required degree of fineness and free from hard or large particles.

The operation is exceedingly simple. The material having been pounded under the hammer or otherwise, is thrown into a vessel more or less filled with a liquid, water, oil, &c. After being thoroughly stirred, it is allowed to partially settle, and the liquid is carefully poured into another vessel. All the coarse heavy grains will be found as a residue in the first vessel; they are collected and used for coarse work. After again stirring and leaving to settle for a longer period, the liquid is again poured off, and the powder thus separated will be the second degree of fineness, so that it may be

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termed No. 2. By successive operations, in which a gradually increasing interval of time is allowed, Nos. 3, 4, &c., can be obtained; that is to say, a series of powders of the same material but presenting a greater degree of uniformity in the size of grains and of gradually increasing fineness. It may be observed that when the powder of the requisite degree of fineness is nearly attained the mass should be left to settle until the following day, or, rather, until the fluid is clear; then decant carefully so as not to lose any of the deposit.

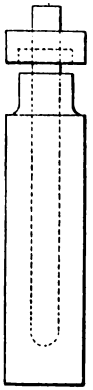

FIG. 2.

When treating a material that is soft and friable, it should be crushed between the fingers, as by using a hammer hard grains of foreign matter might be accidentally intermixed.

Oil may be used for decanting diamond powder or oilstone dust for smoothing; water for rottenstone or tripoli; alcohol for hartshorn, &c.

169. To prepare diamond powder. — Select rough diamonds of a blackish tint, of such a size that there are four or five to a carat. These are crushed in a hard steel mortar of

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the form indicated in fig. 2, the pestle being provided with a small stuffing box that can be brought down on to the mortar to prevent the escape of diamond-dust; but it is well to first crush one stone, with a single blow of the hammer on the pestle; remove all the fragments and examine the end of the pestle; it will be found that a number of particles have bedded themselves in it, and these should be examined to select pieces to serve as drills and gravers (**209**). The larger fragments serve for gravers, and particles should be sought that are as nearly as possible triangular prisms about 1-50 inch long for making drills. The other stones may be treated in similar manner till enough fragments are found. Now place all other pieces in the mortar, and continue for two or three hours striking the pestle with a hammer, turning it partly round after each few blows to prevent the powder from imbedding itself in the steel. When no "bite" is perceived in rotating the pestle, the diamond is sufficiently reduced; it is shaken out of the mortar into a watch-glass containing the most limpid oil attainable, and if necessary the fragments are released by a steel spatula, at the same time striking the external surface of the mortar with the hammer. Thoroughly mix the oil and powder, subdividing this latter as much as possible by rubbing against the glass with a spatula; allow the mixture to rest for an hour and pour off the liquid into a second glass, leaving the larger particles behind. Leave the oil in the second glass for four hours and again decant into a third glass with the same precautions. This is left for eight hours, and the next glass for sixteen hours. When all the powder has thus settled pour off the oil, and the several degrees are ready for use in the manner indicated in articles **207—210.**

Some jewellers prefer to leave the powder for two or three days in a mixture of equal parts nitric and sulphuric acid in order to dissolve particles of steel. The acids are then much diluted with water, left for some days and decanted. Then wash the powder in two fluid ounces of pure alcohol,

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leave for two days, decant and dry, and afterwards treat with oil. The operation is long and hardly necessary.

SMOOTHING.

170. If a surface is smoothed well, the labour of polishing will be diminished by at least one-half, and it is an essential preliminary if a good gilding on brass is required.

The materials most frequently used are emery and oilstone dust for steel, pumice and water of Ayr stone for brass. The stones should not be traversed by veins, nor exhibit hard grains. Powders should be freed from large or hard grains by decantation (**168**), and it is advisable to repeat this operation several times in order to have several degrees of fineness.

SMOOTHING OF BRASS.

171. Every watchmaker knows that after finishing the object with a smooth file, it is smoothed, first with a blue stone or a rather coarse water of Ayr stone, and then with one of finer grain. If the brass is to be gilt, the operation is concluded with a series of circular strokes, so as not to leave any striæ or bright spots ; if the surface is to be *spotted* or watered the final strokes should all be parallel.

A soft piece of charcoal applied with water may also be used to objects intended for gilding ; in other cases it is used with oil.

172. Wavy or watered smoothing.— This is done with water of Ayr stone and oil carefully prepared, or with a piece of wood charged with oilstone dust, &c. The oiled corner of an emery buffstick can occasionally be used.

To obtain wavy undulations on a smooth piece of metal, the finger should first be placed at the point of commencement of the undulations. Resting the wood or stone against this finger, it is moved a little in a straight line, and then in a series of semi-circular wave-lines, from

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right to left or left to right. The finger is advanced through a definite distance and the operation repeated, and so on.

A very good watered surface can be produced with soft charcoal. With a view to increasing the regularity in the marks, a rule may be laid on the object, against which the charcoal is brought.

Parallel watering is usually done mechanically, but any watchmaker can secure regularity by the following simple device :—

Fix a graduated rule *t g* across the cork (fig. 3, plate IX.) and two pins A A, to form stops for preventing the stick or stone from travelling too far. A division of the rule is made to correspond with the line *v v* ; and, when the first line has been traced, advance the object by one, two or three graduations of *t g*, according to the interval that is to be left between successive undulations. Then trace the second wave, and so on.

173. Wavy and curvilinear smoothing.—These are of two kinds ; some are entire circles, which we shall proceed to consider ; others radiate in curves from the circumference to some other point of a circle as, for example, many of those that are met with on keyless ratchet wheels. The latter will be discussed farther on, when discussing the smoothing of steel (**178**), for the process is identical for both steel and brass, except that with the latter-named metal and nickel the stick may be replaced by a strip of zinc or tin, and coarse rouge is used.

174. Circular snailing or spotting.—This is produced on a special tool by which several motions can be given to the object, but watchmakers, as a rule, so seldom have occasion to trace this class of ornament, that it will suffice to explain how it can be produced by the appliances that everyone has at hand.

The universal mandril may be employed for the purpose, but, in that case, the operation is a very slow one, whereas,

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with an ordinary pair of turns, especially if driven by the foot, it can be done both rapidly and well.

Adjust a rest of the form shown at S (fig. 6, plate IX.), taking care that the height of the centre is sufficient; the small rectangular bed *a a* has a projecting edge, divided by equidistant graduations. To the headstock of the lathe is attached, at *b*, a piece of bluestone or wood. Having set the rest at a convenient height, and holding the object to be spotted, P, on the rest, bring it in contact with *b* when in rotation. When the mark is made, lean the object from *b*, slide it along *a a* so that its edge coincides with the next division and make another mark, and so on until an entire row is completed. Then raise or lower the rest and repeat the process for a second row, and so on.

Instead of applying oil to the acting face of *b*, which would have to be renewed at each operation, it is usual to cover the object P with oil, if *b* is a stone, or with oil mixed with the substance used for smoothing, if *b* is of wood. If this precaution is taken, the work will progress much more rapidly.

When the object operated upon is of irregular shape it must first be attached to a rectangular plate and then proceed as already stated.

A still more simple method, but one that is, in certain cases, quite sufficient, consists in passing through the poppet-head a centre of the form *f d* (H, fig. 6), which is caused to rotate by the fingers or any other means.

To make spottings that, instead of being parallel, radiate from the centre to the circumference, the rest *a a* must carry a disc that can rotate on a clamping screw, and is maintained in position by a finger, with an even number of equidistant divisions on the circumference of the disc. The object to be operated upon is then fixed to the disc, and a stick used, the diameter of which is equal to the distance between two radii that pass through a pair of graduations on the disc; for example, the small circle *s* (fig. 4, plate IX.).

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A series of circular spots is then made by gradually rotating the disc. Now replace the rod *s* by one of the diameter *n*; advance the support until it corresponds with the position *n*, and make the second range of circular spots, and so on. The figure renders any further explanation unnecessary.

The watchmaker who has clearly followed what precedes will be able, should occasion require it, to construct a special tool acting with certainty; but it will be well to remember that there is a great advantage in driving the spotting stick by the foot, and bringing it down on the object by a small hand lever, after the manner of the drilling machines used in factories.* (See article **306**.)

SMOOTHING OF STEEL.

175. The smoothing of a steel object is commonly done on a piece of cork, with a large iron polisher charged with oilstone dust and oil. If a flat surface, it can be finished with a copper polisher or on a sheet of glass. In the case of staffs, arbors, &c., that are not intended to be polished subsequently, a certain degree of brilliancy is given to the surface by rubbing with wood, usually pegwood, or with a stick covered with the finest emery paper and oil.

A surface that will not be subjected to friction—as, for example, the head of a screw—can be smoothed rapidly and well with a dry emery buffstick if little metal has to be removed, and the polishing can then be at once proceeded with. Only one cleaning is in this case necessary, for after the emery it will suffice to rub with pith and pass a brush over the surface.

For ordinary work, smoothing a staff or head of a screw with dry fine emery and finishing by the friction of rather hard pith backwards and forwards, will give a fairly satisfactory surface.

* See also two designs in the *Horological Journal*, Vol. XXI. 1878—9), pp. 21 and 52.

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176. White and dead smoothing.—To produce a graining, the piece of steel must be previously smoothed in the ordinary way, perfectly flat and free from scratches; the graining is produced by rubbing the object on a sheet of ground glass with the finger, taking very small circular strokes, especially towards the end of the operation. The degree of success depends on the quality of the oilstone-dust employed. It must be very fine, and it will be a prudent precaution to decant the powder in water, or preferably in oil, and not to use the earlier deposits (**168**).

When the oilstone dust is not very good, it may be washed in hydrochloric acid, which dissolves most of the hard grains, but it will require to be thoroughly washed in water afterwards, on account of the difficulty there is in removing the last traces of acid. Of course such a method is only to be resorted to on an emergency.

Perhaps the most difficult piece to grain is a keyless barrel ratchet, because if the operation is at all prolonged the edge of the ratchet may become white before the centre and it may even polish. If this happens, the ratchet should be held in the hand and rubbed with a piece of pith cut to a blunt point with a flat end. By this means it is easy to act on the centre, avoiding the edges.

177. Dead white or frosted surface.—After having grained the steel in the manner above indicated, if it is required to obtain a dead white frosted surface, employ a mud formed of Arkansas stone dust, or the sticky deposit on a whetstone which is more readily obtained. It should not be too yellow, as the result is all the better according as a greater number of steel particles are mixed with the oil; at least, so we are informed by some very good workmen. A large piece of elder-pith having been divided into two equal parts lengthwise, is smoothed with a new, clean file; the mud is spread upon it, and the piece of steel is moved over it with circular strokes as in producing the graining. In this case the movement can be rapid. If the operation be

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well done, and if the oilstone dust used be of good quality, the object will after being cleaned, present a beautiful uniform white surface in which the graining is still visible. Experience and knack are everything in the proper conduct of such an operation, especially in its concluding stage.

The surface may be cleaned in pure benzine mixed with a little sulphuric acid, followed by a very clean buffstick, which will impart a brilliancy to the metal.

M. Beau recommends fine Turkey oilstone powder mixed with turpentine as the best preparation for rapidly producing a dead smooth surface on steel-work.

Workmen that are constantly engaged in graining employ a foot-wheel for the purpose. The ground glass is fixed so that, although not rotating, a small circular motion is communicated to it. The steel is then simply held against it; indeed, several pieces can be grained in this manner at once.

To the methods above described we would add the following, which is successfully practised by several English workmen :—

They lightly fix the ratchet, for example, by its edge, and finish the smoothing with a piece of pith more or less charged with pure charcoal powder and fine oilstone dust. Here also knack is mainly instrumental in ensuring success.

178. Snailing.—To produce the snailing on a fusee or on keyless wheel-work, the device shown in fig. 18, plate VI., and described in paragraph **376**, can be used. The ratchet or fusee is mounted between one pair of centres and driven by a cord from a foot or hand-wheel. The copper or iron lap, having a diameter equal to about three times that of the surface to be snailed, is charged with fine emery powder and oil, or oilstone dust, &c., and set in contact with the face of the steel, which thus causes it also to rotate. The direction of the snailing will be the same, whether the rotation is to the right or left. If it be required to change the direction, the relative positions of the two pieces must be reversed.

It has been already observed that brass and nickel can be

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snailed in the same way, employing a zinc or tin lap and coarse rouge (**173**). In some cases, hard wood laps can be used for these softer metals.

In keyless steel wheels a beautiful snailing can be obtained with Arkansas stone mud (or, in its absence, the greasy mass from an oilstone) mixed with polishing rouge.

With reference to the little tool shown in fig. 18, plate VI., it may be observed that, if the axes of both the steel piece and lap were driven by bows or otherwise, the surface would be polished and not snailed.

In the absence of the tool here referred to, any workman can easily construct one for the purpose which will adapt to the mandril or a foot-lathe : in order to help him in doing so we will describe one designed by M. Cadot, of Paris.

179. *Tool for snailing.*—This is shown in fig. 5, plate IX., and we would at the outset observe that it can be used equally well for polishing. To a shoulder at the extremity, A, of a piece of steel rod, B (which takes the place of the slide-rest cutter) is riveted an L-shaped piece $c\ c^1\ d$, and to the point d is firmly fixed by a screw or rivet, the upright piece $d\ h$ parallel to $c^1\ c$; this piece is enlarged at h so as to give a bearing to a hardened steel screw, with a hollow point, in the axis of B : the lap is supported between this screw and a hole in the centre of A. The figure will suffice to indicate the form of this lap which is dished internally as shown by the dotted line. It is made of iron or copper if intended for use with hardened steel.

The piece to be snailed is fixed to a chuck of the foot-lathe (or to one of the chucks adapted to the mandril described in par. **403**) and, having fixed the rod B in place of the cutter, the lap is brought, by means of the slide-rest screws, in contact with the steel, taking care not to set it up to the centre, as snailing that starts from the centre is not so good. Having charged the lap with fine emery and oil, &c., the object is rotated and it sets the lap also in motion.

It was mentioned above that this tool can be employed

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for polishing: for such a purpose use fine rouge, replace the lap by one of bronze or bell-metal, fix a ferrule at *i*, and, while the object turns in the lathe, rotate the lap with a bow.

By fixing a rod at L instead of at B, the tool is at once adapted to be used in an ordinary pair of turns, as it can be fixed in place of the T-rest; but it is not so easy to secure parallelism of the two surfaces.

180. To restore the watered surface in nickel movements, &c.—Although the following is employed for nickel (or rather German silver) it may be well to observe that it is equally applicable to all other metals.

As these nickel movements are not gilt subsequent to being repaired, it frequently happens that the water marks on the surfaces do not correspond. By the aid of the following device watchmakers can correct this fault, but we must warn them that, as in all operations involving dexterity, they must first make experiments in order to acquire the requisite manual skill.

On a small open frame C C, fig. 1, plate XIII., fix several parallel bars *f l*, *e d*, &c., and on two of these adjust a slide *p o n m*, with two strips glued underneath so that it can travel up and down between *a* and *b*. On *p o n m*, fix a guide of convenient form, as G; and, after cementing the piece, say A, that is to be watered on a board resting on the bench, place the frame C C above it and trace the figure of the guide with a pegwood stick charged with polishing material. The same figure can be reproduced in parallel rows as the guide can be moved up or down.

By varying the shape and position of the guides, the water lines can take the form of waves, festoons, circles or ovals. In the two latter cases the guide has apertures of the requisite form, and the board that carries A, not being more than half the size of the aperture, can be moved about by hand or by a tool.

If preferred, one of the bars, as *e d*, can be graduated

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and arrangements can be made for clamping the slide by screws in any position.

These explanations will suffice to enable any intelligent watchmaker, after a few trials, to imitate successfully any of the beautiful watered surfaces that are, on a manufacturing scale, produced by machinery.

As regards the material to be used, first mix medium rouge and putty powder in equal proportions. It will be possible to decide from the shade obtained whether more putty powder should be added, because, when there is too much rouge, the surface does not acquire a good white colour.

POLISHING.

181. To polish brass.—When it is required that a surface be maintained perfectly flat, first dress with somewhat coarse water of Ayr or blue stone and then go over with a softer stone. Next work with fine rottenstone and oil on a felt or buffstick for objects of large dimensions and on a piece of pegwood for smaller articles. They are then soaped, washed and dried in sawdust. (**151.**)

The work can be accomplished more rapidly, but without maintaining a perfectly flat surface, by first employing pumice-stone and oil spread over a large piece of soft wood or felt. It is then cleaned and polished with rottenstone.

When the form permits of it, a tin disc charged with tripoli and rotating in a lathe can be employed.

Observations.—Pumice-stone is powdered fine and then sifted. In using rottenstone a piece an inch or two cube is crushed between the fingers into a cup of water, and this is decanted so as to give several degrees of fineness (**168**). The polishing can be best effected by using old wood from which the sap has dried up: French chalk has but little action if the polisher with which it is applied is from the animal kingdom, horn for example.

182. To polish watch-wheels, &c. — Although the

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operation of polishing is extremely simple, it is very important that a certain degree of manual skill be acquired by practice, as otherwise the work is never of the best.

We will here enumerate several methods of procedure, in order that, after trial, each can select the method with which he finds himself most successful.

Smoothing.—The smoothing should be carefully done with very soft water of Ayr stone, free from veins and hard grains and perfectly flat. The wheel must then be well cleaned.

Polishing.—In polishing, rods of walnut or boxwood, of tin, bronze or zinc are used. A buffstick and burnisher are also employed.

The materials applicable are rottenstone (with oil or alcohol, being made very thin in the latter case), tripoli, prepared chalk, polishing rouge, crocus, &c. These materials have been sufficiently described in articles **165—7.** Workmen sometimes prefer to make mixtures of two or more substances, but it is more usual to employ them separately.

183. *First method.*—After smoothing and cleaning the wheel, it is polished while resting on a piece of cork, where it is held between the fingers which cause it to rotate; the best rottenstone is used and is applied by smooth pieces of boxwood, about 8 inches long, which are filed to a bevel edge. It is best to have the grain of the wood crosswise and the polishers should be of sufficient thickness to prevent their bending when in use.

The rottenstone can be replaced by tripoli and the boxwood by walnut. Some wheel polishers prefer a triangular stick of pure tin or zinc which is often planed to ensure perfect flatness; rouge, rottenstone or tripoli can be used with it.

The wheel, after being well washed in soap and hot water, is thoroughly dried and finished with a fine buffstick in good condition, while it rests on a cork covered with smooth felt: this operation is with a view to prepare the surface prior to using the burnisher.

Some polishers instead of the dry buff stick prefer one

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charged with a little rouge, tripoli or rottenstone moistened. But such preparations must be applied very sparingly as they involve a risk of rounding the edges.

The burnisher is next rapidly passed over the surface of the wheel, which rests on cork covered with a linen rag or on a piece of wood covered with smooth paper. Some give long backward and forward strokes with the tool; others give semi-circular movements. It will be found sufficient to give short strokes from half an inch to an inch in length. A slight motion of the wrist is all that is required and after a few trials the necessary skill will easily be attained. We cannot say more. Practice must also be relied on for determining the most suitable pressure.

The burnisher, about half an inch wide and four inches long, is curved in the direction of its length. A straight burnisher might be used but it is less safe: the angle of the burnisher set against the pinion should be rounded off.

The burnisher is cleaned and restored by drawing across a large flat piece of walnut charged with rouge of very good quality and perfectly pure (see article **247**). After being washed a little white wax is passed over it, and then it is again rubbed vigorously with a piece of cloth or a buff-stick; finally with a soft linen rag. When a tendency to stick shows itself this operation must be repeated.

184. *Second process.*—By this method the surfaces are somewhat rounded off at the edges. But although not so pleasing to the eye, this circumstance involves no inconvenience except that, when burnishing, the burnisher would not at once come in contact with the entire surface; we need not, however employ the burnisher.

Laying the wheel on a cork, some workmen smooth the wheel by covering it with oil and fine tripoli and rubbing with a walnut-wood stick. Others spread a layer of such a mixture first on the stick and then rub the wheel. When no more lines are observable across the surface of the wheel t is cleaned, placed on a fresh cork that is covered with a soft

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linen rag, and polished with a fresh buffstick (or one that has already been used for a similar purpose) and an abundant supply of rouge or even fine rottenstone and oil may be used. The buffstick receives a semi-circular movement in all directions in order not to needlessly round the edges of the teeth and the crossings.

It is then washed in warm water, bathed in alcohol and dried with a fine linen rag.

185. *Third process.*—After smoothing with a very soft stone, rub it with a piece of the root of boxwood cut across the fibre on which is a layer of the following composition :—

Two-thirds rottenstone mixed with one-third Castile soap, worked into a paste with a few drops of water so that, although not a liquid, it can be spread out at will.

Make the wheel move backwards and forwards between the fingers while resting on a smooth good cork without a linen rag, and, as the operation nears its completion, a semi-circular motion should be given to the wood.

Wash with soap, boil in alcohol and dry.

The wheel can be burnished on a cork without any linen rag and the (curved) burnisher should be moved with short circular strokes from the centre towards the circumference, gradually working up towards the extremity of the burnisher : the same portion of the burnisher should not pass twice over the wheel (see also article **166**).

For common work, fairly satisfactory results may be obtained by using French chalk and a piece of hard wood.

Clock wheels are polished with a piece of felt and rottenstone. They are subsequently soaped, washed and dried in sawdust (**151**).

186. To polish lever escape-wheel teeth. — The Lancashire escape-wheel makers employ a triangular frame carrying at its corners, (1) a cutter to slit the teeth, (2) a cutter to shape them, and (3) a revolving piece of hard leather of a section corresponding to the form of the space. This latter is charged with the finest glossing stuff used dry,

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and the sides of the teeth of six wheels at a time are polished by revolving this disc in each of the spaces in turn. It is hardly necessary to observe that the operation is completed before the wheels are removed from the cutting engine.

187. To polish sinks or oil-cups.—A piece of pegwood rounded at the end is used for this purpose, rotating it with the bow or in a lathe: the watch plate or cock should be inclined in varying directions to the stick in order to remove scratches. If a very high polish is required it may be given by following with a stick the end of which is covered with wash-leather charged with rouge.

TO POLISH STEEL.

188. The polishing must always be preceded by a very thorough smoothing, either with oilstone dust, fine emery, or coarse rouge. If any lines are left to be erased by means of fine rouge, the operation becomes tedious and is rarely successful. The oilstone dust is applied on an iron or copper polisher. When it is desired to preserve the angles sharp, at a shoulder for example, the polisher should be of steel.

When using diamantine an iron polisher, drawn out and flattened with a hammer, answers very well.

With fine rouge, a bronze or bell-metal polisher is preferable for shoulders; and, for flat surfaces, discs or large zinc or tin polishers, although glass is preferable to either of these.

After each operation with oilstone dust, coarse rouge, &c., the polisher, cork, &c., must be changed, and the object should be well cleaned—preferably by soaping; perfect cleanliness is essential to success.

Fine rouge or diamantine should be made into a thick paste with oil; a little is then taken on the polisher or glass and worked until quite dry. As the object is thus not smeared over, a black polish is more readily obtained, and

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the process gets on better if the surface is cleaned from time to time.

189. To get a good black polish.—As just pointed out, this is mainly secured by using very little polishing material at once, in a very little liquid on either the polisher or glass plate and drying up quickly. If the surface does not prove satisfactory at first, it will often be found that a final rapid and light application of dry diamantine or rouge on a piece of glass or pith will produce a brilliant black polish.

If operating on an axis or staff, polish as well as possible, first erasing the marks of the graver or file and then, holding the ferrule between the fingers, rotate it with one hand and with the other rub the axis lengthwise with a pegwood stick charged with rouge or diamantine.

A rod will show a black polish if it be rubbed lengthwise with emery paper of gradually increasing fineness, oil being applied with the finest quality.

To polish flat surfaces.—The swing-tools, &c., described in pars. **378—381**, are employed for this purpose. In their absence, place the object on a sound piece of cork covered with a clean rag and rub with a long strip of ground glass.

To polish a square shoulder.—This may be done with one of the tools described in pars. **374—6**; or, in their absence, the workman may proceed as follows :—

Fix a rod in place of the T-rest of the turns, and set it in such a position that the polisher rests on this vertical rod when lying flat against the shoulder. Another and better method consists in cementing or otherwise fixing in the plane of the shoulder a brass disc of such dimensions that the polisher is constrained to remain flat.

To polish a hollow, or the rounded corners of teeth.—See the methods described in articles **578—80**.

To polish pinions.—A tool for doing this expeditiously is described in articles **612—4**.

Observations.—The corner of the polisher that is used for

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polishing a shoulder should be neither right-angled nor too acute. In the first case it would round off the shoulder, and in the second it would soon become distorted and leave dull radial marks on the surface.

Diamantine should not be used for polishing the acting surfaces of pivots, the pallets of escapements, &c., since this material as well as emery is liable to leave particles embedded in the steel which occasion rapid wear.

CEMENT, WAX, RESIN, &c.

190. The principal uses to which the watchmaker applies cements is for fixing objects in the lathe, pallet-stones in position, as well as locking and unlocking pallets, ruby-pins, &c.

The selection of a cement or wax is not a matter of indifference; fine sealing-wax causes objects to adhere firmly together, but many of the best workmen prefer refined shellac. Certain kinds of wax are too dry, the consequence being that a false stroke of the graver will often detach the piece; others are thick and soft, and are apt to heat rapidly under the action of the burnisher or polisher, so that the object is displaced. It is only by making a series of trials that the efficacy of the material can be ascertained. Some workers claim that a mixture of sealing-wax and shellac gives good results. (See also article **671**.)

191. Mode of applying cements.—When employing wax, resin, cement, &c., for uniting two objects, it is important to note that the mode in which it is applied has an important influence on its efficiency. The following observations on this point are due to M. Sibon, and the reader will be able to select those portions that have reference to his work.

When two objects are united by a cement, this will lose much of its value if unskilfully applied, and, in order to use it to the best advantage, the following practical rules should be observed:—

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1. The surfaces to be united must be quite clean.

2. The less cement, wax, &c., that is interposed between them, the better will they adhere. This is owing to the fact that with a thick layer the object has, at the junction, no more rigidity than that of the cement itself; as a rule this is more fragile than the material it is employed to unite.

3. There should be perfect contact between the cement and the surfaces. With a view to securing this, the object must be first heated to a point such that the wax or cement cannot solidify without having first had time to effect a perfect union.

This remark is especially applicable when using sealing-wax, mixtures of resin, shellac, and similar materials. They will not adhere firmly unless the surfaces have been heated very nearly to the point of fusion of the cement. The sealing of letters offers an example in proof of this assertion. When the seal has been used several times in succession or has been left too long on the wax so as to become hot, it will adhere and cause some inconvenience if further employed.

With hot melted glue adhesion is best secured by friction or a moderate pressure.

Sealing-wax is excellent for uniting metal to glass or stone, providing they are sufficiently heated to melt it; for, if applied to cold surfaces, it will not adhere at all. By heating two pieces of glass or stoneware sufficiently to melt shellac, a small quantity will suffice to make them adhere firmly together; notwithstanding that every one has seen such joints, very few succeed in making them, from the simple reason that they do not recognize the necessity of heating a delicate piece of glass or china to the point which is essential for securing a good result.

In conclusion, the principal obstacles to adhesion are air and dirt. The first is always present; the second is due to accident or carelessness. All surfaces are covered with a thin layer of air that is very difficult to remove; its influence

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prevents highly polished metal from being moistened when immersed in water. So long as this layer of air is not displaced, the cement cannot adhere to the surface to which it is applied, because it cannot come into direct contact. The most effective agent for displacing this air is heat. Metals heated to about 75° C. (170° F.) are immediately moistened on being plunged into water, hence it follows that, as regards cements that are applied in a fused state, heat is the best means of bringing them into intimate contact with the surface.

We would add that, in addition to possessing this advantage, the application of heat also renders the surfaces more penetrable to the layer of cement, after the manner of soldering, and makes the interlocking of the molecules more perfect; this explains the greater degree of tenacity of a well-made joint with only a thin layer of cement.

192. To set in wax in the lathe.—Trace a series of concentric circles on the face of the chuck with a graver point, after turning it true; this will increase the adhesion of the cement. Then the flame of the spirit-lamp is held under the rotating chuck and, when this is hot enough, its surface is covered with a layer of shellac or sealing-wax, and the object is held against it. Holding it in position with a piece of pegwood supported on the T-rest, the lamp is removed and the lathe kept rotating until the cement sets. The cooling can be hastened by applying a small moist sponge, but it should not set too suddenly.

If the object requires to be very exactly centred, its position must be ensured while the cement is still soft by means of a long pegwood stick in its central hole (**405—8**), This stick is held in position until the cement sets, steadying it between two fingers close up to the chuck. The slightest excentricity will be indicated by a motion of the free end of the stick.

If the object is round, and has no central hole, it must be centred by its circumference, holding the pegwood in front,

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or resting against a corner of a circular elevation or depression, as, for example, the collet of a wheel, or of a cylinder riveted to its balance, &c.

The beginner should make a number of trials; they will enable him both to acquire lightness of touch, and to recognize the proper degree of softness of the cement for centring, as well as its tenacity.

When it is essential that the two faces of the object be strictly parallel, a precaution is necessary; this consists in leaving on the face of the chuck a slightly projecting circular rim with a fine smooth edge, and of a diameter rather less than that of the object. By moving this latter backwards and forwards after applying it to the wax, and pressing it into close contact while cooling, the requisite parallelism will be secured.

193. To fix a pallet-stone, &c., in position.—To fix a pallet-stone or an end-stone by means of shellac it is usual to place small pieces of the latter round the stone when in position and apply heat. But very often the lac spreads unevenly or swells up; and this, in addition to being unsightly, is apt to displace the stone. The inconvenience can be avoided as follows:—The pallets are held in long sliding tongs and, taking a piece of shellac, heat it and roll it into a cylinder between the fingers; again heat the extremity and draw it out into a fine thread. This thread will break off, leaving a point at the end of the lac. Now heat the tongs at a little distance from the pallets, testing the degree of heat by touching the tongs with the shellac. When it melts easily, lightly touch the two sides of the notch with it; a very thin layer can thus be spread over them, and the pallet-stone can then be placed in position and held until cold enough. The tongs will not lose the heat suddenly, so that the stone can easily be raised or lowered as required. The projecting particles of cement can be removed by a brass wire filed to an angle and forming a scraper. (See article **640.**)

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To fix an end-stone, the cap must be held by its edge in the sliding tongs, and shellac carefully applied round the edge of the hollow. It is advisable to hold the cap in a small tool formed of two parallel blades, as when reversed so as to press the stone on a flat surface, the shellac will spread over the end-stone, from which it will be removed with difficulty.

For mounting diamond drills, &c., see article **216.**

ENAMEL.

194. This name is applied to an opaque glass with which various metallic compounds, such as oxide of tin, phosphate of lime, borax, &c., have been incorporated by fusion. The colour, of course, varies with the substance so added.

Willis (article **670**) recommends the following as a good white enamel for dials: silver sand, 14 parts; borax, 10 parts; red lead, 18 parts; nitre, 2 parts; oxide of tin, 12 parts; flint glass, 4 parts; and binoxide of manganese 1-50th part. But a good deal of care is requisite, both in selecting the materials and in preparing the enamel, in order to ensure a pure colour of any desired shade; it is, therefore, often desirable to purchase the enamel ready prepared.

In applying enamel, regard must be had to the relative dilatation of the metal to which it is applied, the two being so combined as to expand and contract together; otherwise there is danger of the enamel cracking, either at once or shortly after it has set.

Enamel may be applied to gold or copper. Associated with the latter, it forms the ordinary dials of watches and timepieces, and, with the former, it serves for making enamelled gold dials or cases. The gold should be of 22 carat, the 2 carats of alloy consisting of equal parts of silver and copper. If the gold is of a higher standard, it will not adhere so well, and, if lower, there will be a further danger of melting the metal before the enamel is fused.

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Silver is apt to cockle on the application of heat, and enamel applied to it presents a bubbly appearance.

A full description of the method adopted in making enamel dials will be found in articles **670.**

195. Application of enamel in the cold.—We are indebted for the following particulars to M. Fournier, of Dieppe, a well-known enamel maker:—

There are two kinds of false enamel for application, when cold, to damaged dials.

The first, a mixture of white resin and white lead, melts like sealing-wax, which it closely resembles. It is advisable, when about to apply it, to gently heat the dial and the blade of a knife, and, with this, to cut a piece of enamel of the requisite size and lay it on the dial. The new enamel must project somewhat above the old. When cold, the surface is levelled by scraping, and a shining surface is at once produced by holding at a little distance from the flame of a spirit lamp. It is necessary to be very careful in conducting this operation, as the least excess of heat will burn the enamel and turn it yellow; it is, however, preferable to the following, although more difficult to apply, as it is harder and does not become dirty so soon.

The second false enamel contains white lead mixed with melted white wax. It is applied like a cement, neatly filling up the space, and afterwards rubbing with tissue paper to produce a shining surface; if rubbed with a knife blade or other steel implement its surface will be discoloured.

PRECIOUS STONES.

196. The principal precious stones used in watches, chronometers and regulator clocks, in their order of hardness are: diamond, ruby, sapphire, chrysolite.

A watchmaker, although he may not have had any previous experience of jewels, can easily ascertain their relative

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hardness by rubbing one against the other. The softer will be scratched by those that are harder, and the stones that can be marked by a file may be thrown aside as useless (**122**).

197. Diamond.—We shall make a very brief reference to this stone, as it is not used except for the end-stones for balances of chronometers and high-class watches.

Splinters of diamond are employed for drilling materials of a less degree of hardness, and fragments fixed at the end of a rod are used for turning very hard steel; diamond dust is the principal material used for working precious stones, polishing, &c. (see articles **165** and **169**).

198. Ruby.—This jewel, of a rich velvetty red colour, exists in three principal varieties: oriental, spinel and balas rubies, which differ as regards their chemical composition.

From a jeweller's point of view, the value of a ruby is enhanced by its rich colour and transparency; but this is not the case in regard to its applications in horology, for which hardness and capability of taking a high polish are mainly necessary.

The specific gravity of the three varieties are, oriental, 4·2; spinel, 3·7; balas, 3·6.

The first of these is the best, since it is the hardest, both taking a better polish in the first instance and retaining it for a longer period.

In comparison with the other varieties its specific gravity is greater and it possesses a brighter colour, but will often be found to be less transparent.

Spinel and balas rubies are frequently met with that are very beautiful to the eye, but their hardness is inferior to that of the sapphire and even of the chrysolite. They must be carefully excluded from all good work, for, either in consequence of the inferior hardness or of the mode in which the oxide of iron, magnesia, &c., is combined, or of other causes, oil rapidly deteriorates in contact with them, and

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the moving parts, especially if they are of steel, soon show signs of wear. The rubies themselves also suffer, and it is by no means uncommon, especially in the case of the duplex escapement, to meet with such jewels quite rough and even pitted on their acting surfaces.

199. *False ruby.*—In a certain class of watches, a variety of stones pass for rubies that are known to jewellers as rubicelle, rubace, rock ruby, Brazil, Siberian or Bohemian ruby, rose ruby, &c., &c., the hardness of which is even less than that of rock crystal. Pivot-holes made of these imitations of the real ruby are worth less than plain brass settings.

200. Sapphire.—The colour of this stone, sometimes even milky, passes through all the shades of blue. Like the ruby, there are several varieties that differ appreciably in regard to hardness. The hardness of oriental sapphire is equal to that of oriental ruby; both consist of nearly pure alumina, coloured by a little oxide of iron; their chemical composition thus being the same, they only differ in regard to colour. It is, then, a great mistake on the part of watchmakers to prefer spinel or balas rubies in place of oriental sapphires.

The sapphire is more brittle than the ruby.

The other kinds of sapphire, such as water sapphires, are not true sapphires; they are soft and should never be used in horology. The density of the oriental sapphire is about 4·01, whereas that of other kinds is only 2·58.

201. Chrysolite.—Under this name lapidaries include a variety of stones of yellow-green, apple-green with shades of yellow, and other colours.

That known as oriental chrysolite, which is the same as the oriental topaz, has a beautiful pale yellow colour with shades of apple-green; it is the most highly esteemed. This stone has a sufficiently high degree of hardness for use in watchmaking, as it will scratch rock crystal. Its density varies from 3·73 to 3·00.

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The other varieties, ordinary chrysolites, come very low in the scale of hardness. They can be scratched by quartz, rock crystal and even by the file, and are thus of no use for watches.

202. Agate, Carnelian, Topaz.—Only the varieties of the stones already considered that are termed oriental can be used for the pivot-holes or the pallets of astronomical regulators, but for the escapements of the ordinary time-pieces of commerce, such, for example, as the pallets of Brocot escapements (see *Treatise*, page 554), the topaz, agate or carnelian may be used. When of the hardest kind, and capable of receiving a high polish, they will very efficiently resist the friction of brass teeth. As to the softer kinds, they are inferior to hardened polished steel for pallets.

WORKING IN PRECIOUS STONES.

203. The methods adopted for working in the precious stones are in great part kept secret by those who practise them; it is, however, well known to watchmakers that jewels are usually worked and polished with powdered diamond, and the following details will afford all the information necessary to enable the reader to make a jewel of any required form. Where not otherwise stated the information is taken from a work published by N. Dumontier.*

204. Tools for working jewels.—These are all of simple construction, and can be made by any watchmaker if, indeed, he has not them already to hand.

(1.) A small lathe arranged to receive chucks, fixed to the bench or in a vice, and driven by a foot-wheel. Its form resembles that shown in fig. 5, plate II.

(2.) Two circular laps of copper and one of tin about

* *L'art de travailler les Pierres précieuses à l'usage de l'Horlogerie et de l'Optique.* Paris. 1843.

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2 inches in diameter and $\frac{1}{8}$th inch thick; these present a flat face for grinding, smoothing and polishing the stones, and are adapted to the nose of the lathe.

(3.) A small barrel (that also screws into the nose of the lathe) with six brass covers perforated at the centre, on which to cement the jewel-holes, when enlarging, smoothing and polishing their holes.

(4.) A flat steel circular cutter half an inch in diameter, for slitting stones. Also two similar discs, one of copper and the other of tin, of the same size, and having sharp edges, are occasionally useful.

(5.) Two small laps, one of copper and one of tin, to smooth and polish cylindrical stones. These laps are mounted in place of the T-rest, or in the slide-rest, in such a manner that they can be rotated in a horizontal plane by a bow in a manner that is sufficiently indicated by fig. 9, plate VIII. (article **624**). See also the arrangement described in article **172**.

(6.) Two chucks adapted to the lathe, on which to cement the jewels for drilling, turning and polishing.

(7.) A number of small broaches, spindles with concave and convex ends, &c., for smoothing and polishing jewel-holes, convex and concave surfaces.

There may also be added a small steel plug mortar for powdering the diamond (**169**), and a flat steel plate with a block for working up the powder.

205. Selection of Stones.—This is of the first importance. By the aid of a powerful lens or a microscope ascertain that they contain no cracks, air cavities or black specks; avoid stones that are milky, preferring such as are marbled, and in which the directions of crystallization seem to cross one another, as they are the hardest. The hardness may be tested by trying them one against the other (**122**), but an experienced workman needs only to note the amount of resistance it offers to the operation of cutting on the lap. The density also affords a valuable means of determining

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the nature of stones. (See above notes on the several kinds.)

206. To find the axis of crystallization of a stone. —It is well known that jewels differ from glass in that they form crystals of certain definite forms; they are therefore termed "crystalline," whereas glass is "vitreous." If a jewel-hole is drilled in any direction other than the axis round which the crystal may be assumed to have been formed there will be difficulty experienced in the drilling and polishing; the edges of the hole will become rough during the act of rounding them off, and the hardness will appear to be irregular. This point seems, however, to be ignored by the majority of jewel-hole makers, although the determination of the most suitable direction presents no difficulty.

Obtain, from any optician, two tourmaline plates cut parallel to their axes of crystallization and with their faces polished. Mount them in a light frame parallel to each other so that each can rotate independently of the other round the axis through their centres; it is convenient if a light spring tends to bring the plates together so that a stone can be held when placed between them. Or such an arrangement can be bought ready made at most opticians: it is known as a tourmaline polariscope. If this instrument be held up between the eye and a light, and one plate be rotated while the other remains stationary, it will be seen that the light becomes gradually greater or less according to the direction of rotation; and further, if the plates be good ones, a point will exist at which there is nearly total darkness.

To examine a stone, cut and polish on it two parallel faces approximately at right angles to the axis of crystallization; this can generally be roughly guessed at by inspection. Place it between the plates (when set at their darkest position), and not only will the light be in part restored but beautiful coloured rings will be formed. If they are circular

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the faces of the stone are at right angles to its axis; if not, incline it till the rings become so, and the axis will then coincide with that of the instrument. In case the rings are not observed at all, the stone must again be cut at right angles to the original direction, and the experiment repeated. If they still do not appear the stone is unsuitable for drilling, but may be used for pallets, locking-stones, ruby pins, &c.

The stones to be examined in this manner must be larger than those commonly met with, and if cylindrical rubies can be obtained they are to be preferred, as it is then only necessary to slice them across their axis.

It should perhaps be observed that these precautions can only be taken in making jewel-holes for the higher class of clocks, chronometers and watches. The cheaper class must of necessity be cut in such a manner as their figure may suggest.

207. Making jewel-holes. — Having selected 20 or 30 stones of about the same height, cement them to a smooth brass or copper plate, heated to melt the cement. Hold this plate in contact with a revolving copper lap in which the coarser quality of diamond powder (**169**) has been embedded by means of a hard steel block; the lap is moistened with water.

When one side of the stones is true, soften the cement and, after washing, place them in a vessel containing spirits of wine heated by a lamp. After doing the same to the plate again cement the stones to it with the trued sides downwards, and grind the other faces until the desired thickness is arrived at. Clean the stones and smooth them on the brass lap charged in a similar manner with a finer quality of powder.

The stones are now ready for drilling. This may be done with diamond powder or with the diamond drill, both of which methods will be explained.

208. *To drill with powder.*—In drilling with powder the

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stone is fixed with sealing-wax or shellac on a carrier that is adapted to the tool-holder of the slide-rest, this carrier being provided with a vertical slide so that by the screws in three directions the stone can be accurately centred; it is, moreover, so arranged that the stone can be advanced to or from the drill by pressing with the finger axially. Drill a small hole in the centre of the chuck and, after fixing a piece of steel in it that has been hardened and tempered to a greyish colour, turn a point on it about twice the length of a pivot, to serve as a drill. This point must be slightly thinned backwards to prevent it from choking in the hole and its end should be flat so as to retain the powder.

When the stone is exactly centred, place No. 2 diamond-powder on the end of the drill, and press the stone gently against it, constantly releasing it from the drill for an instant at a time. The hole will be perforated in from 8 to 15 minutes according to its depth, during which interval the powder should be renewed two or three times. Remove the stone and fix it on the barrel-chuck cover so as to turn true in the lathe; then turn out the oil-cup with a diamond graver of suitable form. See again that the stone is central, and re-centre it if this be found necessary. This is done with the smooth conical end of a soft round broach or a pegwood, as explained in articles **405—8,** a lamp being held under the chuck at the same time.

209. *To use the diamond drill.*—Having centred the stone on the chuck, as explained in the preceding paragraph, set it in rotation and bring a sharp-pointed diamond graver against its centre, pressing lightly and resting the handle on the T-rest: a minute central mark is thus made in the stone for maintaining the drill axial. Selecting a diamond drill of convenient diameter, moisten it in the mouth and present it to the mark, applying a gentle pressure the amount of which can only be ascertained by practice. It is to be observed that a number of stones should, if possible, be drilled at the same time, for the hand is apt to lose the

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requisite knack if only one or two are perforated at a time.

210. Smoothing and polishing.—When the hole is made through, remove the stone and invert it on the chuck. The diameter being less than that ultimately required, pass a brass broach charged with No. 3 powder through the hole, giving it a gentle axial motion while the stone revolves, and taking care to avoid pushing it so far forward as to lock in the stone, and holding it very lightly between finger and thumb. When sufficiently smooth, clean with rotten wood or soft bread, and treat it in a similar manner with a copper broach and No. 4 powder. Then again clean and use a tin broach and powder No. 5. Next, taking a small bone cone, smooth the angles of the holes: then use a copper wire with rounded end for smoothing the oil-cup (with powder No. 3): follow as explained for the hole with the finer degrees. Using a finely pointed pegwood that passes through the hole, *marry* or round off the internal angle between hole and oil-cup (the powder that remains in the hole being sufficient for this purpose) and do the same to the outer circumference of the cup with a copper spindle of somewhat larger diameter.

Round off external angles with a diamond graver followed by a copper polisher, the end of which is cup-shaped. The flat face of the stone is polished with a small copper disc and No. 4 powder, pressing it lightly with the finger at the same time that a circular movement is given to it; finish with No. 5 powder. Or the stone may be detached and the flat face polished by working on a ground glass plate, a pegwood point being passed into the hole to form a handle.

Re-set the stone, inverting it, on the chuck, centring it as explained in **405—8**. The other side is then polished in the same manner, using such tools as its form may require.

Having thus completed the stone, examine it carefully with a powerful glass to ascertain that the hole is highly

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polished and the angles rounded off, &c. It is then ready for setting.

211. Setting jewel-holes.—Whether it be a plate, cock or bouchon in which the stone is to be set, the piece must always be cemented to a chuck and the hole accurately centred. Turn it out to a depth corresponding to the thickness of stone, and make a circular groove round the hole thus made with a round-pointed graver, only leaving a very thin fillet of metal on the inside. The stone should fit easily in the hole, but without play, and should pass in to such a depth that its surface is slightly below that of the plate, &c., when there is an end-stone; in other cases it must of course often depend on the end-shake to be obtained. At the same time it appears desirable that it should always be slightly below.

Clean out the setting and place a small quantity of oil in it to prevent the stone from flying out when made to rotate; or it may be rendered still more safe by a pointed pegwood stick held in the hand. The stone is fixed in position with a small conical burnisher (as, for example, the point of a round broach) very carefully polished so as to avoid all abrading action; if an excess of metal is forced over the surface of the stone it is removed with a graver. The surface of the brass is finally smoothed with hemp stem or pegwood and tripoli in oil, followed with polishing rouge in spirits of wine.

English jewel-setters often do not turn the groove, but leave a projecting edge round the hole which is pressed on to the stone with a burnisher.

Some forms of tools for fixing new jewel-holes in position will be found described in article **373**.

212. To make end-stones.—The details already given will enable any intelligent workman to make end-stones. If one of diamond in a brass or steel setting is required, take a small rose-cut stone, turn out a hole in the chuck to receive it, and, after cementing in position, turn off the corners with a diamond graver so as to be able to set it.

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For making end-stones of ruby, sapphire or chrysolite, flatten a face, using the laps Nos. 1, 2, and 3 in succession or a plate of ground glass. Then cement with the flat face towards the chuck, and turn to the requisite form with a diamond graver. Polish with the cup-ended brass and copper spindles, and set, if requisite, in the same manner as a jewel-hole.

213. To make pallets, unlocking pallets, &c.—This may be done on the lap or by using files of soft steel, copper and tin. In the first case the stones are roughed out while held by the hand, and the required form is given while holding them in a small carrier that fits into the T-rest support, but the forms of such stones are so various that no special details can be here given. The diamond powders of different degrees of fineness are used, as in making jewel-holes.

214. To make semi-cylindrical locking stones, ruby-pins, &c.—The stone must first be made approximately cylindrical on the lap No. 1, so that it may be turned with the diamond graver. Drill a hole in the chuck, cement the stone in it and turn it in this manner. When true and of the requisite length and diameter, round off the outer end and smooth with a cup-ended spindle, then polish with powders 3 and 4 successively. Round off the sharp corner with a cup of rather greater curvature. The cylindrical surface is polished by means of a small lap carried on a vertical spindle in a frame fixed in the T-rest support, and caused to rotate rapidly with a bow, the lathe-head, also revolving at the same time (**179**). The lap-carriage should have a vertical screw adjustment so that it may be brought just into contact with the stone; it is supplied with the several degrees of powder in turn. Now drill a hole in another chuck of the diameter of this cylinder, fix it in position and finish off the opposite end.

To form the flat face along the axis of the stone it is cemented to a support in place of the T-rest and brought

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against the revolving lap in the lathe; or the same result may be attained by using a brass file.

A small appliance whereby such stones may be cut mechanically has been described by Curzon, and to it the reader is referred.*

215. To make a duplex roller.—At the present day this operation so rarely has to be done that only a few words can be devoted to its consideration.

Very pure rubies must be selected, and the hole drilled as explained in **209**; if the drill is too short it must be introduced at opposite ends, and the two holes made to meet. After smoothing the surface, the notch is cut with the thin steel cutter referred to in article **204**, the roller being cemented to a support that replaces the T-rest. When the steel disc charged with powder No. 4 is revolving very rapidly, advance the roller under it by a screw. The notch is polished by a small copper file of suitable form, and its corners rounded off by a tin one of square section, one edge of which enters the notch.

216. To mount diamond drills and gravers.—Drill a hole or file a notch in the end of a piece of brass wire to correspond with the fragment of diamond; heat the end in a spirit lamp and lay on it a piece of good sealing-wax or shellac. When this commences to melt, set the diamond in position and leave the whole to cool. Diamond drills are very commonly mounted at the end of a pin that has had its point filed off; mark a point on the end with a graver and drill the hole, which should be very shallow. Holding the pin in a pin-vice with its point projecting about 1-10th inch, heat the vice in a lamp, and proceed as above explained.

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* *Horological Journal*, xxiii. (1880—1), p. 79.

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PART III.

HEALTH AND MANIPULATION.

PRESERVATION OF HEALTH.

217. Some of the following directions may perhaps be considered to be over-minute and too restrictive ; but they are not so. Good habits contracted in youth are easily maintained, and, when the watchmaker has tried them long enough to convince him of their influence on his health, he will experience no difficulty in keeping them up.

THE SIGHT.

218. When working at any small mechanism such as a watch it is necessary to use the glass, but this practice is apt to produce inflammation of the conjunctiva or cornea and a weakening of the eyesight ; a too frequent and prolonged use of the glass will have the same effect as using spectacles that are too strong.

In order to preserve his eyesight, the watchmaker should take the following precautions :—

He should not retain the glass at his eye by a contraction

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of the muscles for more than a brief interval of time. The glass holder, which can be at once set in any desired position, has therefore much to recommend it.

Drill a few holes in the frame of the glass to avoid or at least diminish the inconvenience that arises from the heating of the enclosed air, as well as from the deposition of moisture on the surface of the glass.

Do not use glasses of too great magnifying power ; they needlessly fatigue the eye.

Only use glasses that are truly achromatic. If compelled to use the ordinary simple glass, place a ring of dead black paper inside the frame and against the lens, which, by diminishing the field of view, will reduce the inconvenience due to spherical aberration.

It is hardly necessary to advocate the use of a green card-board shade to the lamp, as they are so generally used by watchmakers. It should be so arranged as to protect the head and eyes from radiation, and card-board is preferable to metal since it radiates less.

Working at night and by artificial light, more especially by the dazzling light of gas, fatigues the eyes much more than with ordinary daylight, and the workman will find it a relief, if obliged to work by artificial light on very minute objects, to rest his eyes frequently on large stationary bodies. If he can do so, it is a great comfort to bathe the eyes in cold water.

It is a good practice to habituate oneself to the use of either eye with the glass.

By adopting these simple precautions, how many of our fellow-workers who are now only able to see objects indistinctly and suffer from incipient blindness would have preserved their sight uninjured. And there is yet another precaution that has been pointed out by Dr. Haltenhoff, of Geneva. He has shown that by avoiding an excessive indulgence in alcoholic drinks or tobacco, many old watchmakers in that town have succeeded in preserving their sight

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unimpaired, and it is impossible to doubt the truth or over-estimate the importance of this fact.

The same authority draws attention to the necessity of taking care that, before adopting watchmaking as a trade, youths should ascertain that they do not suffer from progressive near-sightedness, which is often hereditary, as in such a case they would most certainly be compelled to abandon it in after life. Boys should not be set to work on such small objects as the details of a watch too early in life, before the membranes of the eye have assumed a certain degree of rigidity.

Mr. Brudenell Carter, a well-known ophthalmist, is of opinion that the habitual use of the glass by watchmakers has the effect of actually developing and preserving the power of the eye.

THE BODY IN GENERAL.

219. It is often found that an old, or even a middle-aged watchmaker is irritable, often tired and soured. This arises, not so often from an over-excited uneasiness in regard to his trade, an explanation that is usually urged, as from a derangement of his digestive organs brought about by the habit of life he is compelled to adopt. Prolonged working at minute horological mechanism is perhaps more wearying to both the mind and body than any other trade or occupation.

To avoid its ill effects the watchmaker should adopt the following precautions as far as possible :—

Do not use a stool with stuffed seat, but prefer one of cane or wood.

Take care that the relative heights of the board and stool are such that an excessive compression of the muscles of the chest, &c., is avoided during any long operation that renders it necessary to maintain the body in a constrained position.

A stool with adjusting screw, similar to a music-stool, is convenient from this point of view.

Change the position as much and as often as possible,

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especially when working with the file or graver. With this object in view many workmen have a second board of such a height that they can work standing.

When using the lamp let it always be provided with a cardboard shade as already recommended.

A screen to protect the head from the direct heat of the flame is often found advantageous ; in fact, the watchmaker should adopt the advice of Boërhaave : " Keep the head cool and the feet warm."

Let him always remember that nothing does more harm than sitting to the bench immediately after a meal. He should allow an interval of half an hour to elapse and with some temperaments, even this is not enough ; during this period he should only do work at which it is possible to stand. A little exercise, such as a walk that is not hurried, will be still better : it will stimulate the circulation and stretch the muscles that have been maintained in a constrained position for a long time through the prolonged attention and slight motion that his labours involve.

USE OF THE FILE AND GRAVER.

220. The first operations that a watchmaker ought to learn are to file flat and square, to turn round, to forge, to hammer-harden a piece of metal without deteriorating it. These accomplishments are but too much neglected in the modern training of an apprentice, an omission that is partly owing to the want of good instructors and partly to the shortness of the time he can afford to devote to learning his trade.

TO FILE FLAT AND SQUARE WITH BOTH HANDS AT ONCE.*

221. It is a very common practice to place an old file in

* A large amount of information on this and cognate subjects will be found in Holtzapffel's *Turning and Mechanical Manipulation*, Vol. II.

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the hands of an apprentice, to fix in the jaws of a vice a piece of metal, either brass, iron or steel, and to set him to work rubbing and filing the surfaces with great labour, the only result being that they are utterly mis-shapen and covered with brillant spots.

This method is bad. The action of the file is mechanical and the problem that has to be solved is the following: to produce good work in the shortest possible time, and with the least expenditure of force. It is therefore only by very slow degrees that an apprentice can hope to acquire the requisite ability, if he is set to work trying to shape an object in some hard metal before he knows how to maintain lines straight and surfaces flat. Not knowing how to proportion his effort to the resistance to be overcome, and allowing the file to travel irregularly over the surface, he gets confirmed in the tendency to give a rocking motion to the file, whereby the surface is left round, and he will find it all the more difficult to throw this habit aside.

It is far better to let him commence on round pieces of common wood, filing with a rasp or coarse-cut file without removing too much at once. By this means he may rely on learning to file flat and square by the eye alone without the aid of a straight-edge.

When he works well in common wood, he can be set to file harder woods, box for example, roughing with a rasp and finishing with a new bastard file. He should not be allowed to leave hard wood until able to file a surface so well that, on placing a metal rule across it in any direction, it is found to be flat.

222. Let him then advance to brass which, if cast, should be previously dipped in acid to remove the hard surface, as this should not be filed off. The resistance it opposes would cause a jerky motion of the file that would be apt to disturb the slight amount of decision the hand has already acquired.

As brass opposes a considerable resistance, the pupil should be carefully watched with a view to preventing too

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rapid movement and an excessive pressure, involving waste of power, while he fancies the work is being proportionately advanced; the manner in which the file is applied to the surface should also be observed, taking care that little or no pressure is applied during the backward stroke. The teacher should both explain and demonstrate that the main secret of success consists in a perfect equilibrium between the actions of the two hands; one should increase as the other decreases with the horizontal motion of the file since the two levers in use, namely the portions on either side of the point of contact, are continually the one increasing and the other decreasing.

By filing steadily and attentively the hands will gradually acquire the requisite sensitiveness or tact that enables each to adjust the pressure in proportion to the other, as well as the knack that enables them to maintain the surface flat. It is important to avoid short and jerky movements.

Practical instruction from a competent teacher must be relied on to complete the directions here given; no written instructions can replace it.

It is advisable to use new or nearly new files in the above lessons; the wear will have brought them into good condition for working iron or steel.

Proceed with these metals as already explained in regard to brass, and special attention must still be given in order to prevent hurry on the part of the pupil. The files remove less metal at a time and a greater pressure is necessary, so that he does not make such rapid progress as with brass, and this gives rise to a tendency either to use new files, which are soon spoilt, or to give the stroke too suddenly, while applying considerable pressure, especially during the return stroke. He thus heats his file, breaks off the crests of the teeth, which become embedded in the metal and do much to further damage the file. Moreover, he will lose some of the sensitiveness of touch that his hand has already acquired.

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223. It would perhaps be well to subdivide the day into three parts for as long as appears necessary; the first to be devoted to filing, the second to turning, and the third to forging and cold hammering.

By this means he will be quicker in acquiring the requisite skill of hand and eye, and, when he has attained to this ability, it will be time for him to practise himself in the management of various tools. Feeling certain of himself, he will soon become quick in his work.

It is prejudicial to the true instruction of a pupil and a false economy of both time and money, to let him commence either a clock or watch before arriving at this point. He will experience difficulty in making even the simplest pieces, which, besides being very badly made, will take up a long time; he will keep forgetting as he goes on, because, owing to the slowness with which he works, the construction of a machine occupies months or even years, whereas it would only have occupied a few weeks or months if he had possessed sufficient manual skill to enable him to handle properly the file and graver.

We insist specially on the need of this preliminary training of the young horologist, because, with very rare exceptions, if a pupil is set to delicate details before he is master of his tools, he works with a want of decision and, therefore, with difficulty. He will, as a rule, make a workman of but moderate ability, and will soon become disgusted with his trade, from the mere fact that he cannot work with ease and rapidity.

Time is an element of success; hence gratuitous apprenticeships for short terms, that become a tax on the master if he does not soon make use of his pupils' services, will very seldom produce good watchmakers.

TO FILE FLAT WITH ONE HAND.

224. When an object is to be held on a cork or wood

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block fixed in the vice with one hand and filed with the other hand, special care must be taken to lay the file flat without any hesitation after each return stroke, and the hand should be able to *feel* if the file is wrong in this respect and to at once bring it flat. After the pupil has learnt this, he will very soon be able to adjust the pressure and the force exerted in moving the file horizontally, so that it shall remove an equal amount from the entire surface operated upon. It often happens that the object can conveniently be rested upon a finger of the left hand while the right hand holds the file. The maintenance of the file flat is in that case much easier.

225. *Mechanical device for filing flat.*—This (the *pradel*) consists in placing behind the workman a horizontal bar, on which rests one end of the file handle, prolonged for the purpose to about a yard in length; thus the file has two points of support: the bar, adjusted at a convenient height, behind the workman, and the object to be filed flat fixed in the vice in front.

This method, while convenient for amateurs, may be utilized in teaching an apprentice, letting the supports be hinged at one end and press at the other end on a rather strong spring index, which must be prolonged so as to be brought under the eye of the pupil.

The displacement of the index will show him every false movement of his hands, and will guide him in adjusting them. It would be best if the prolongation of the handle were as light as possible, but rigid and arranged so that the file can be held naturally.

TO TURN CYLINDRICAL PIVOTS, ETC., AND SQUARE SHOULDERS.

226. Just as in working with the file, advice and demonstration by a good master are here indispensable.

The materials should be worked in the same order as is

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explained in pars. **221-4**; that is: wood, brass, iron, steel, hardened and tempered steel; no one sample being set aside until the student can turn it perfectly round, flat on shoulders, &c., and smooth throughout.

He should turn for a long time, whether it be by the wheel or bow, exclusively with the point of a square or lozenge-shaped graver, the end of which is ground off on a slope; this is the only possible method of learning to turn *true*, and it enables the workman to acquire great delicacy of touch.

Owing to carelessness or to the fact that, when first beginning, they were set to work on metal that was too hard or rough, most learners turn with gravers that are ground to very blunt points; as the graver bites less they are obliged to apply a proportionately increased pressure, and only succeed in tearing the metal away, subjecting it to a kind of rolling action, and rendering the hand heavy. If a pupil will not practise turning with the graver point, so as to preserve it intact for some time, dependent on the nature of the metal, he will never be able to turn perfectly true.

The bow should be used through its entire length, and with a motion that is progressive, not jerky. The knack of the turner with the bow consists mainly in keeping the simultaneous actions of the two hands quite distinct; one drawing the bow downwards, while the other depresses the point of the graver supported on the T-rest, and these two movements of the hands must be performed at the same time but quite independently.

Irregular and sudden depressing of the graver point, or engaging it too deeply, causes its frequent rupture. This also sometimes arises from the fact that the point is not removed with sufficient rapidity, so that on raising the bow the metal catches it while travelling in the reverse direction; the graver is thus drawn slightly towards the work, and its point will be found too close in when the bow again descends.

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As has been already observed, the bow, which must not be too short, should be used to its full length with a regular but not rapid motion. Afterwards, when the hand has learnt how to manage the graver, the speed can be gradually augmented. There is always a danger of losing time, teaching and, therefore, money if pupils are too much hurried in their lessons. Before trying to work quickly, they should at any rate know how to work fairly well.

Short and sudden movements of the bow will make the object turned jerk; it will be heated, and the sharp angles of the graver will jamb in the metal: thus there is less work done although there is more noise, and this is done badly.

227. When sufficient experience has been gained in turning with the graver point, and a trial is made with the cutting edge, do not attempt to remove much at a time by pressing heavily, but take the metal sideways so as to remove a continuous thread, using all the points of the edge in succession and the entire length of the bow. The metal will thus be removed as a thin ribbon or shaving. When the hand has had some experience, it will be found easy to remove long strips, and the work can be done quickly, although there be no hurrying in the movement of the bow. (These remarks are equally applicable to turning with a wheel.)

228. Hardened steel that has been let down to a blue temper requires certain precautions. If the graver is found not to cut cleanly, it must at once be sharpened, and no attempt should be made to remove more metal by increasing the pressure of the hand, because the steel will burnish and become hard under a point or edge that is blunt, and the portions thus burnished are sometimes so hard as to resist the best gravers. The only way of attacking them is to begin at one side with a fine graver point which must be sharpened for each stroke; at times it becomes necessary to temper the metal afresh before it will yield. It is asserted that by moistening the point of the graver with petroleum

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it becomes more able to attack hard substances, and that a mixture of two parts petroleum and one part turpentine enables it to turn very hard steel with comparative ease. Indeed, for all turning it is a common practice to moisten the graver with oil, water, turpentine, or by simple introduction into the mouth.

We have frequently seen apprentices, and even watchmakers themselves, careless as to the proper sharpening of their gravers and thinking that they could hasten their work by the application of considerable pressure ; they thus produced bright spots that required several hours of work before they could be removed.

There is one essential condition for ensuring good work with the lathe, and this consists in the perfect roundness of the points or holes of the runners or centres, and of the holes or points that are supported in them : this perfect truth is nevertheless very rarely met with, for it is noticeable that barely one watchmaker in ten knows at the present day how to roll such a point. We shall subsequently indicate the precautions to be observed in order to secure this accuracy (**254**).

The diameter of ferrule is also to be considered ; if it is too small, the bow will slip and the object will only rotate by jerks ; if too large, it loads the object unnecessarily and the velocity of rotation is reduced, since for the same stroke of the bow the ferrule must make a less number of turns. Moreover, if it is of large diameter, only a light bow must be used, because otherwise the force applied would be excessive.

Swiss workmen—at least the great majority of them—turn indifferently with the right or left hand. This is a very useful accomplishment easily acquired when young.

The working of various tools, such as the English or Geneva mandril, and any lathe driven by a treadle, will be a great help in developing the sense of touch and in making it more certain.

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But it must not be forgotten that, in order to turn well, the lathe must be well made and planned; without this, no accurate work can be done. The lathe is the first and most important of tools, and a great number of very serviceable accessories can be added to it, which, unfortunately, but few watchmakers know how to make properly. As a rule they content themselves with a simple pair of finishing turns on which but a comparatively small amount of work can be done.

Without committing the mistake of having a too great multiplicity of tools, let the pupil rest certain that a well-planned set of tools in good condition both facilitates and abridges his work and renders it more perfect.

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PART IV.

TOOLS AND APPLIANCES.

WORKSHOP FITTINGS.

229. Before proceeding to describe the various forms of lathe and the several small tools that the watchmaker should make for himself as occasion offers, either during his apprenticeship or immediately after, with a view to increase his manual skill or to extend his experience, it will be well that he take note of the principal conditions that should be satisfied by the ordinary tools that he will have to buy, as well as the precautions to be observed in their use and some improvements of which they are capable.

230. The bench or board.—This should be fixed in front of a large window that affords a good light. The various hooks, recesses, &c., for holding the bows, files, hammers, &c., as well as the drawers, should be well in sight, not only in order that the hand can at once take hold of whatever tool is required, but also to enable the workman to restore them to their place immediately after use. By doing so he will have no occasion to retain on the bench any but those tools that are very frequently or continuously in use.

It is an excellent habit, conducive both to well-planned and rapid work, and which can be easily acquired by a little attention during an apprenticeship, to always place the same

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tools in the same places, as the bench will then never be encumbered. By this means loss of time in turning over a number of objects in order to find one that may be small is frequently avoided.

This observation is of minor importance to specialists who require but a small number of tools ; but it is of the first importance to a workman that is engaged in the repair of watches.

The head of an establishment, who can arrange for himself as he thinks fit, will do well to provide two boards, at one of which he can work standing. It is an excellent practice to vary the position of the body (**219**).

231. The stool.—Those with cane seats are to be preferred. The height of the bench and stool should be so related that the muscles of the chest are not too much cramped, especially if the workman is engaged on an operation that occupies a long time and obliges him to maintain a stooping position. The stool with a screw is advantageous in this respect.

232. The lamp. — Certain precautions in regard to artificial light have already been indicated in article **218.**

233. Bows.—Whalebones can be reduced in strength or rendered more uniform by being filed with a fine rasp, or by scraping their surface with a piece of broken glass. If, instead of fixing a brass end with a hook to the bow, it be desired to form a hook of the whalebone itself, hold the extremity in boiling oil for a short time, when it will soften ; then form the hook, maintaining the whalebone in the required position until sufficiently cool to set. Recently a form of bow has been introduced that consists of a brass handle into which slides a steel wire bent into the requisite form ; the strength of course depending on the thickness of steel wire used.

234. Oilstones.—It is impossible to maintain the points of gravers in good condition if care is not taken to keep clean

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and flat the surface of the stone on which they are set; if it has suffered irregular wear, the level may be restored by rubbing the stone on a flat smooth board covered with a thin paste of fine sand and water. Most kinds of oil thicken on the surface rapidly, when the graver will slide over without being ground down at all, turning round in the hand and thus destroying the flat face and wearing the softer parts of the stone, rendering it uneven. A strong solution of potash or soda is very effective for removing this gummy mass; benzine is also recommended for the same purpose. Various substitutes for common oil are used; such as the mineral lubricating oils or petroleum. Dr. Latteux advocates the use of a mixture of alcohol and glycerine, the proportion of the latter decreasing as the extent of metallic surface in contact with the stone at once increases. Thus, for example, in setting a razor the stone will bite better if alcohol be in excess; but for a graver, of which only a small surface touches the stone, the amount of glycerine present should be relatively much greater.

235. Small grindstones.—When it is necessary to remove a good deal from the face of a graver, the operation will take too long on the oilstone, and there would be considerable difficulty in maintaining the face flat; recourse must then be had to the grindstone, but it should be remembered that care is needful when using it. The grindstone must always be thoroughly wet in order to avoid heating the graver, as its cutting power would then be destroyed. The emery wheels described in par. **165** can be used for this purpose, but they are, for the most part, inconvenient on account of the rapid increase they occasion in the temperature of the metal. Some forms of emery wheel can, however, be moistened just as the grindstone.

When the cylindrical surface is rendered irregular by use, take a piece of sheet-iron, the tail of an old file or a cold chisel, and hold it with one hand firmly on a support

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against the edge of the stone, which is rotated by the other hand. The surface can thus be made smooth and true providing it is only attacked gradually and the handle is not turned too rapidly. An excessive velocity will heat the iron, which then is less effective and is more rapidly worn down; whereas, with a slow motion, the iron will relatively wear little and the stone more. A rough diamond mounted at the extremity of a steel rod affords an excellent means of trimming a grindstone, and is at the present day generally used in factories.

236. Glasses.—Some particulars have already been given in regard to these simple microscopes in article **218.**

237. Files.—A new file should never be used for steel; it is best to employ it for some time at first on brass, taking care not to use it too roughly. If employed for steel at once or if sharp quick strokes are applied, the cutting edges of the file will chip off and the hard particles will be embedded in the metal operated upon; the work will thus be bad, and the file itself deteriorated. A file that has been carefully used and has passed gradually from brass to steel will last four or five times as long, and will always work well.

Watchmakers often fix files into handles by driving them firmly into round holes in the handles; this practice frequently leads to their being cracked, and the following method is preferable:—

Take an old worn-out file or a piece of iron of the same form as the tail of the file to be fitted; heat it several times to bright redness and drive it, when so heated, into the handle, taking care to maintain it perpendicular. A hole will thus be formed of the required form, in which the file will hold without there being any occasion to apply excessive force in fixing it in position.

When the surface of a file is choked with particles of iron, copper, wood, &c., while the cutting edges are yet good, it can be cleaned as follows:—Place the file for a few seconds

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in a hot lye of potash in water, and on withdrawal, dry it before the fire and brush the surface with a stiff brush.

238. To renew the cutting edges of files, either of the following methods can be adopted:—

(1.) First clean the file with potash or soda dissolved in water if greasy or resinous substances have to be removed; with hydrochloric acid if it is rusty; and by rubbing with a metallic brush or piece of coke if particles of iron, brass, lead, copper or tin have to be removed. The file is now immersed in a mixture of 1 part nitric acid, 3 parts sulphuric acid, and 7 parts water. As the action of the acids becomes less energetic owing to the combination with iron, the temperature of the mixture must be raised, since rapidity is a condition of success. The time during which the file should remain in this bath varies from 10 seconds to 100 and more, the roughening of fine-cut files being far more rapid than when they are of a coarser cut. On removal from the bath, immerse in lime wash, dry and then cover them with a mixture of oil and turpentine by means of a brush, after which they are ready for use.

(2.) After being cleaned, as explained above, the file is supported in a dish full of water, resting on two cross wires so that all its surface is in contact with the liquid. Now add strong nitric acid in the proportion of 1 part to 8 of the water, mix it thoroughly and allow it to remain for 25 minutes. Remove the file, and, after washing in water and rubbing with a hard brush, place it again in the bath to which a second eighth part of acid is now added, and leave it for 50 minutes. Again remove and brush the file, add a sixteenth part of concentrated sulphuric acid and replace the file in the bath. Then wash successively in pure water and in lime wash (to remove the last traces of acid) and dry. The file will be found to possess both the qualities and the appearance of a new one.

239. *To cut an equalling file.*—It often happens that a workman is called upon to modify the shape of, for example,

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the bottom of a rectangular notch, and he is not provided with a file of suitable shape. In such a case he can adopt one of the following methods of extemporizing a file :—

(1.) Clamping the small steel strip L, fig. 7, plate XI., in a vice, cut the notches with a chisel, *n*, as follows : Holding *n* a little inclined, cut the first notch, *i*. This will slightly raise the metal, presenting a rounded face at the back. To make the next cut, hold the chisel with its edge on L and, after drawing it backwards until arrested by the back of *i*, incline it to the requisite amount and give a second blow with the hammer, then continue the operation till the whole is finished. A few trials will enable any workman to make a small file with sufficient accuracy for his purpose.

(2.) Employ an arrangement similar to that of the micrometer divider (**44**) only more rigid. A study of this article and examination of the corresponding figure (fig. 1, plate II.) will afford all the information that is necessary.

(3.) This is identical with the method of dividing a rule described in **46**, except that the divisions are closer together and the tracer is replaced by a revolving cutter with its axis a little inclined, to give the requisite slope to the teeth of the file. This cutter is supported in a hinged frame and provided with a washer of ivory or other such substance, as seen at *s*, fig. 7, plate XI., to determine the depth of cut.

240. *Beaupuy files and burnishers.*—Most watchmakers are acquainted with the files and burnishers that M. Beaupuy has introduced for rapidly forming conical pivots, the main characteristic of which is that the corner presented to the pivot is rounded to the desired form and roughed ; they do their work rapidly and well, but some skill is necessary in their management. To the instructions which accompany them we would add the following :—

They must never be used when quite new on a pivot that is to be employed in a watch : it will be reduced too rapidly. The freshness must be worn off the cutting edges of the teeth by preliminary use.

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The pressure must only be applied perpendicularly to the surface of the staff as in making a square-shouldered pivot: he file is held against the flat face without pressure. A lateral force will have the effect of straining the pivot and causing it to break.

The corner of the shoulder must not be brought to correspond with the required point in the notch of the Jacot tool until the entire pivot is nearly of the requisite size. Up to this point the pivot should not pass into the notch for more than three-quarters of its length. It is of course understood that, before using these files, the cone must be shaped as far as possible to correspond with the corner of the file. (See A and B, fig. 14, plate XII.) When only a few strokes of the file remain to be given, it should rest on the entire length of the pivot.

If this precaution is not taken, it often happens that, owing to a false movement of the file, the slope, whether it be straight or curved, extends towards the point as indicated by the dotted lines at C, fig. 14, plate XII., and the pivot breaks off.

241. Pliers, tweezers, &c.—It is advisable to have a considerable number of these, as their strength should always be proportional to the force that has to be applied to them. For example, if a pair of sliding tongs is used when a hand-vice is needed, the former will be strained beyond its limit of elasticity and the tool becomes nearly useless.

The same might occur with any other form of pliers or tweezers. In the hands of a good workman, they will last for a long time, but if used unintelligently, without proportioning the size of tool to the force that has to be applied, taking up the first that comes to hand, all the tools will soon become unsatisfactory and the work itself will suffer. It is very desirable to have one or more pairs of brass pliers and tweezers for handling metal work without the risk of scratching. (See article **361.**)

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242. Compasses, gauges, micrometers, &c.—The common compass for measuring thickness, the douzième gauge, is not strictly accurate in its indications. We have given a method of correcting for this error in the *Treatise on Modern Horology*, where micrometers and several forms of compass are fully described. Certain forms of compass used by draughtsmen are described in par. **28**.

The compasses, &c., that will be found described in the *Treatise* are :—

Douzième gauge	page 809
Balance staff gauge	„ 271
Incline gauge	„ 288
Jacot (cylinder) gauge... ...	„ 290
Internal gauge	„ 291
Various thickness gauges ...	„ 809
Micrometers	„ 811
Ruby-pin gauge	„ 462
Cylinder compass	„ 289
Rozé's barrel compass	„ 668
Sliding vernier compass ...	„ 810
Grammaire or dividing plate ...	„ 290 ; also

see article **372** of this work.

Calliper for measuring pallet opening.—See article **644.**

243. *Calliper for mainspring height, depth of sink, &c.*—A simple instrument for taking such measurements is shown at G, fig. 15, plate VIII.

The finger *a* travels over a graduated arc whenever the rod *c* is pressed upwards ; *b* is a fixed stop, with its extremity in the plane of *n*. Any movement of *a* below *o* measures the space traversed by *c* within the line *b n*.

Laying a coiled mainspring, for example, on a plane surface, stand the base *n* of the calliper upon it, and the end *c* pressing on the table will be forced inwards and move the needle. To take the depth of a barrel, press *c* on

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the bottom, allowing *b* to rest on the edge of the cover recess.

It will be evident, from the figure, that *a* and *c* are connected by a spring passing round drums at corresponding axes. The smaller *j* is, the more sensitive will the instrument become.

244. Figure-of-8 calliper.—For ordinary work, the callipers to be bought at the tool-shops will suffice; but when it is required to verify escape-wheels, balances, &c., there is some risk of accidents in consequence of the variableness of the friction at the joint. To remove this source of danger, true the rubbing surfaces in the mandril and replace the brass discs at the centre by similar discs of steel, then carefully re-make the rivet that forms a hinge, after oiling all the acting surfaces. The arms will now move with a uniform degree of stiffness, so that there need be no danger of jerks.

245. Riveting stake and punch.—The holes in a riveting stake are made to increase downwards, so as to avoid any accident occurring through the oscillation of the axis.

The riveting punches made of a plain steel rod, with a hole drilled at one end in the direction of the axis, are the best. Those that are perforated transversely like the lanterns of screw-point tools, do not produce such good riveting, since the parts of the end from behind which metal has been removed are more or less elastic. Methods of riveting will be found described in pars. **365, 626.**

246. Burnishers.—Burnishers will not remain in good condition unless their surfaces are prepared, from time to time; in the case of those used for very fine work, by passing over a buffstick charged with polishing rouge or very fine emery, and other kinds on an emery stick more or less fine, according to the degree of roughness the burnisher is required to possess.

247. *To re-face a burnisher.*—Pivot burnishers are usually

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re-faced by a lapidary; a watchmaker can, however, do it for himself very effectually in the following manner:—Prepare a dry smooth piece of wood, rather thick, and of a width equal to the length of the burnisher. On this board carefully glue a piece of emery paper of a fineness corresponding to the degree of cut required, stretching it as even as possible, and turning the edges down towards the under side. Then lay the board on a firm smooth surface, resting a weight upon it, and allow it to dry.

In using this lap, it is fixed or allowed to rest against the side of the bench; holding the burnisher with two hands at its extremities, the workman places himself at one end of the board, and draws the burnisher along it towards him, maintaining the surface quite flat and applying considerable pressure. On reaching the nearer end, raise it, and after again placing it on the farther end, draw towards the body, and so on.

By proceeding in this manner and always in the same direction, placing the burnisher so that the acting edge is farthest away from the operator, all risk of rounding this angle will be avoided (see also paragraph **40**).

248. Broaches.—Great care is needed in adapting the handles to broaches. Resting the point against a finger of one hand and causing the handle to rotate by two fingers of the other hand, the broach itself should be seen to remain true.

It is a good precaution, suggested by M. H. Robert, to gently draw a piece of iron charged with rouge along the edges of pivot broaches in order to remove the thread of metal from them. Minute particles of this thread would otherwise remain in the holes, and occasion wear of the pivots.

These fine broaches are not fixed in handles, but a piece of sealing-wax is melted on to the upper end; then, holding the broach between two fingers, with its stem downwards, it is rotated while held to a flame, so that the sealing-wax forms a regular oblong handle.

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In articles **309—310** will be found certain additional details in regard to the use of broaches, especially in connection with taps and drills.

For particulars in regard to other small tools used by the watchmaker, see articles **308—381**.

249. Blowpipes.—In order that a long even flame may be obtained, the hole should be of moderate size and perfectly clean round the edge; otherwise the jet cannot be

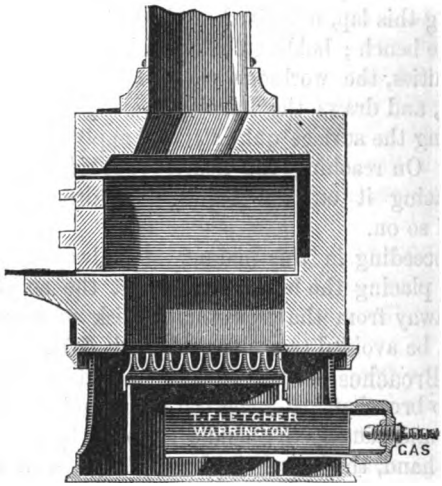

FIG. 3.

straight and sharp. Difficulty will always be experienced by anyone who has not learned to breathe without interrupting the continuity of the blast.

Where a supply of gas is available, the gas blowpipe presents advantages from the point of view of convenience.

250. Small wind furnace.—The workman will frequently have occasion to anneal pieces of steel or to raise to a red heat objects that are too large for the blowpipe; an ordinary open fire aided by bellows is often resorted to in

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such a case. A better plan, however, is to obtain any small portable furnace, provided with a hood that completely closes it at the top, and has a chimney 12 or 18 inches long. Placing this furnace in the open air or, preferably, under a chimney, lay some paper and chips on the bottom and, after covering these with charcoal, set on the hood and apply a light through the small furnace door at the bottom, which is left open. In a few minutes the fire will be well burnt up.

251. Muffle furnace.—This form of furnace is only required when a uniform degree of heat has to be kept up for a long period. Very many designs are to be met with, charcoal, anthracite, petroleum or gas being used as a fuel; but the gas furnace is the cleanest, and a useful form of it, designed and made by Fletcher, of Warrington, is shown in longitudinal section in fig. 3. It will be seen that the burner is of special construction, and the muffle or oven, in which the object to be heated is placed, is at a short distance above it; the heat playing over the entire external surface of the muffle without any of the products of combustion being allowed to enter it. The amount of gas required for a small-sized furnace (the muffle measuring $2 \times 2\frac{1}{2} \times 4\frac{1}{2}$ ins.) is 17 cub. feet per hour, and for the largest size (muffle measuring $4\frac{1}{2} \times 5\frac{3}{8} \times 10$ ins.) about twice this quantity.

THE LATHE.

ORDINARY TURNS.

252. The ordinary pair of turns employed by watchmakers is shown in fig. 6, plate II., and various additions that may be supplied to it are also shown on the same plate. Some of these accessory pieces involve a considerable amount of careful workmanship; but, in our opinion, the time devoted to providing oneself with a well-finished set of serviceable tools is well spent; at any rate, it is open to any reader to

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simplify the tools here described, modifying them according to his requirements.

It is best to buy a somewhat heavy pair of turns; about double the size represented in the plate, for example, as that will suffice for most ordinary work. The centres may be clamped by the ordinary wing nuts or by small levers similar to that of the bench vice, but a preferable method is that described in article **282.** The clamping screw for the T-rest should be carried in a rotating fork-shaped piece, as shown in the figure; it can then be put in any position so as to facilitate the handling of the graver or bow. The bar on which the loose poppet-head, *p*, slides should be perfectly straight and parallel to the prolongation of the centre b^1. All slides on this bar should be provided with a metal tongue, against which the clamping screw presses, thus preventing it from coming directly into contact with the bar itself.

In turns of the size indicated above the centres will be rather thick: this is an advantage as it helps to produce more accurate turning, possessing more solidity and not bending under the clamping screw, as is frequently the case with the centres of the ordinary small finishing turns. If of a fair thickness and well adjusted, the centres can be set quite as easily, and indeed they frequently slide more freely than those of small turns. Moreover they have the advantage of being easily arranged as shown in figs. 7 and 11 of plate II.

Having bought the turns, selecting if possible a pair that has one or more extra poppet-heads, as seen in figs. 4 and 5 (although we shall subsequently explain the manner in which these can be made), broach true the two holes for the centres (**265, 709**), and, if necessary, true those for the bar, so as to secure a firm clamping over a sufficient surface.

253. Ordinary centres.—At *a*, fig. 11, plate II., an excellent form for the end of a centre is represented. The head shown detached at *a* is a small button screwed to the centre and prevented from rotating by a pin. Such an arrangement

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has several advantages: it is only necessary to harden the button; a number of them can be made to be used as required; and if the disc is made rather too large at first, reducing its diameter after the centre holes have been punched in their right positions, they will be found to be truly round and may be as near to the circumference as is desired.

On the ordinary system of making this circle of holes at the extremity of a centre, the metal yields more towards the edge, and thus the fine holes will always be inclined cones.

Other holes are made of sufficient depth with a drill and then carefully chamfered so as to be perfectly conical.

For large or heavy work it would be well to have a pair of ordinary solid centres.

254. Centres for making bearing points: to make such a point.—Generally the centre for this purpose is a round rod turned down to half its diameter and with a projecting edge in which a semi-circular notch is cut as seen at A, fig. 5, plate III. Such a form is bad; the end of the rod operated upon will be liable to jerk upwards while lying in the notch, the file will therefore jerk up also, and the point obtained will nearly always be imperfectly rounded. It is far better to make a cone-plate as described below. Allowing the arbor just to pass through one of the plate holes, and placing the file as shown at *c d*, fig. 5, plate III., after grinding it on the edge *c* so that it shall not damage the centre, a truer point can be obtained than by the previous method.

It should be clearly understood that when a perfectly round point is required (nine times out of ten the section is an oval), the rolling is to be concluded with an exceedingly fine file, then place the point in a hole of the plate that will not permit of its shaking, rotate with the hair bow with the greatest possible care, at the same time turning a portion of the cone; now set the object rotating with this portion of

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the cone bearing against a well-made hole in the cone-plate so that the point is accessible ; this must next be turned and finished with a very smooth pivoting file. It is necessary sometimes to repeat the operation, varying the length of stroke with the bow, for a badly formed point is very difficult to correct ; indeed this cannot be done if the conical hole that receives the point has not been evenly chamfered round its circumference, or if the point bears on the bottom of a hole. For the axis will then be subject to an irregular displacement which makes exact turning impossible.

255. Cone-plate centres.—These are arranged with a detached head, as shown in fig. 7, plate II. This drawing renders all explanation unnecessary ; it will be understood that the dotted lines *d d* are only intended to indicate that the diameter of the disc *c* can be made greater if desired.

256. Centres for replacing pivots.—An examination of fig. 8 will at once make evident the principle on which they are based. One centre carries a sector s, shown in front elevation at s^1: conical holes of varying sizes are made round its arc to receive the extremity of the axis in which a pivot is to be fitted, and the other end is supported by either a hole or point of a small centre at *d*. If this end be a delicate pivot, the small centre must be removed by pressing at *d*, and replaced by a guard-pivot centre (**257**).

As will have been anticipated, the drill is held in the hand and introduced at the side s of the sector ; the centres can be rotated so as to place the pieces *d* and s vertical or horizontal, as is most convenient.

For some further particulars in regard to the replacing of broken pivots see articles **351—2.**

257. Guard-pivot centres.—The portion *n m*, fig. 12, plate II., is held firmly by friction in the centre or runner. The shaded notch at *n* is for rotating this portion with a pair of pliers, or for removing it when necessary. By placing

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a clamping screw at *n*, the necessity of forcing the piece into its place is avoided, and it can be changed more easily when required.

Figure 13 is an enlarged view of the extremity of *n m*, from which it will be seen that the shoulder rests in a conical hole, the pivot being thus untouched. Further explanation is unnecessary.

258. Excentric centres or runners.—These are used for turning objects of large diameter on ordinary turns, or for raising or advancing them towards the front. The excentric point and the large-sized cone-plate centre employed with it are shown opposite each other in figs. 9 and 10, plate II.

A hollow cylinder *d f*, funnel-shaped at *f* and tapped on the contracted portion *d*, is adjusted with a square *i* in the arm A, being clamped firmly in position by a nut, *e*.

The end of a rod, &c., can be supported in the cone *f* of the opening *d f*; but the principal object of having this arrangement is to receive in the cylindrical portion a small centre as seen in fig. 14. It is shown in position at *r s*, fig. 9. The end *s* may be a point or hole as required, and a moderate pressure on *r* will remove the centre.

There is no necessity that the piece, shown in fig. 14, be tightly fitted, but it is essential that the conical shoulder be accurately adjusted to the recess made to receive it, and that the other end be tight enough to prevent shake. If these conditions are observed, the centre will be firm.

259. Centre with loose pulley.—This form of centre is shown in fig. 3, plate II., with the loose pulley in position, and the requisite attachments for driving; fig. 2 shows the details of adjustment of the pulley. These adjustments are made with care and, indeed, refinement, if very smooth working is required, but an examination of fig. 3 will show that for ordinary work the centre and pulley can be arranged very much more simply.

When the pulley is large it is usually made of boxwood

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with a metal centre ; when small, a brass, gun-metal or steel ferrule is employed.

The pulley rotates in the coned recess *g c d*. The cone *d* is formed on the centre itself, which is turned down cylindrical from *d* to *a*, and has a hole at *a* to receive the point of the object to be turned.

The second cone *g*, which slides on with friction, is held in position by the screw *h* tapped on the end of the centre, and a pin prevents *g* from rotating.

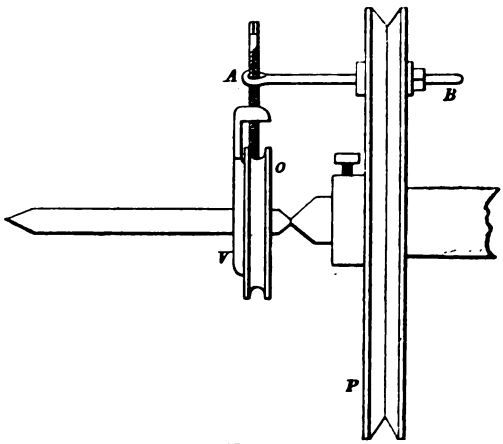

FIG. 4.

The rest will be easily understood. The centre is fitted in one of the poppet-heads, and a small carrier or dog, of which a side view is seen at *t*, fig. 3, and a front view at T, fig. 12, is fitted to the spindle that is to be turned, and rotation is imparted to it by a pin in the loose pulley passing between the arms of the carrier, this pulley itself being caused to rotate by a bow or wheel.

Centres with loose pulleys are of great service, as they enable us to avoid the constant trouble of fitting ferrules to objects, and, if there is little room, the carrier may be as

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thin as possible ; but they are of less relative advantage when a bow is used than when employing a wheel which gives a continuous motion in one direction, as in the first case there is a certain amount of time lost in reversing the motion.

260. Arbor-carrier.—The annexed figure 4 represents a convenient form of carrier for driving taper or other arbors from such a loose pulley. The driver, A B, can be clamped in any position in a radial slot in the pulley, and terminates at A in a ring or fork, through which the screw of the carrier passes in the manner indicated. By screwing this against the edge of the ferrule, *o*, the ring, V, is drawn against its face, so that when the arbor is supported between the runners any motion of rotation of P will be transmitted to the arbor. One driver will serve for any number of arbors, providing their ferrules are not of less diameter than the ring V.

261. Smooth taper arbors.—The taper arbors ordinarily met with in the trade are very hard, and necessarily so : for an arbor that was easily acted upon by the file or graver would be of little use. When a watchmaker is not provided with an arbor of a size required, he generally makes one, but is obliged to let it down to a blue after-hardening, so as to be able to turn it perfectly true with the graver ; and thus it is often left too soft. By following the directions given below, he will be enabled to make them both hard and true.

A quality of steel having been selected that is not liable to much distortion with hardening, pieces of convenient dimensions are annealed. Form the arbor in the lathe and harden it, taking care to adopt the precautions given in the chapter on this operation (articles **84—7**), in regard to the heating, &c., and immerse it vertically in a deep vessel of water or tepid oil. Clean with pumice-stone or by other means, and heat the arbor by rolling on a hot body until the points are of a bright yellow colour ; because these points, if left too hard, are liable to be brittle.

Place the arbor in the turns and verify its truth ; if this

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is fairly good, smooth and polish the arbor; but if, on the other hand, it deviates considerably from a straight line, it must be rejected; for, with good steel and the hardening carefully done, there is never much error to be corrected, and this can be done with a lap.

262. Having set the arbor with one of its ends in the lantern centre, *s*, fig. 13, plate IX., a small lap, M, charged with fine emery, is held against it and caused to rotate slowly on its own axis, while at the same time a slight lateral motion is imparted to it. The arbor must also rotate. Good results may be obtained by using an iron polisher resting on two points, as at P, fig. 12, plate IX.

When both points have been thus adjusted, place the arbor between a pair of runners of a strong depthing tool or, preferably, of the tool shown in fig. 18, plate VI., and described in article **377**, and set a roller, C, fig. 13, plate IX., to rotate between the second pair of runners, which are loose in their poppet-heads but capable of a longitudinal traverse, being united by a U-shaped piece of metal, *b d*, fig. 18, plate IV. Connect the two ferrules with the cone pulley of the distributor (or use two strong bows) and cover the cylinder with fine emery and oil; then bring them in contact and set them in rapid rotation, constantly moving C (fig. 13, plate IX.) backwards and forwards as indicated by the arrows. The operation must be continued until the arbor is found to be perfectly true.

It is essential that, (1) the tool be solid; (2) the points are held without play; and (3) that the two revolving bodies be brought very gradually together.

263. Instead of the cylinder C, the flat face of a lap of the form B, fig. 12, plate IX., may be used, but it must be moved in the directions indicated by the arrows and, at the same time, made to rotate on its own axis; this rotation being effected by a cord passing to the distributor by which the arbor itself is caused to revolve.

Observation.—The arbor produced in the manner here

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indicated will, of course, be cylindrical, whereas those ordinarily employed are slightly conical. But with the explanations already given every watchmaker will be able to arrange an appliance that is adapted to maintain the conical form. For example, the following may be given as a simple means of doing so:—Make several runners of the form A (fig. 13, plate IX.) that are alike with the exception that the holes in their ends are excentric to varying degrees, as shown at *a*, *e*, *i*. With such an assortment it will always be possible to ensure that the sides of the cylinder and arbor are parallel, and, therefore, in contact throughout their length. The excentric runner must only be used on the side of the tool to which no end movement is given.

264. To temporarily lengthen the bed of a lathe.—If an ordinary pair of turns is found to be too short to take a given piece of metal, it may sometimes be temporarily adapted to take in the increased length by means of two centres that each carry a projecting angular piece (*c* and *d*, fig. 8, plate XIII.). An examination of this drawing will show that, in an ordinary pair of turns, if the poppet-head P be at the end of the lathe-bed, no greater length than *f g* can be turned; but, with the centres here described, at least the length *h j* can be operated upon.

TURNS WITH LATHE-HEAD.

265. To make the poppet-heads.—It is the best plan to purchase turns that are already provided with the head-stocks and other attachments shown in figs. 4 and 5 of plate II., such for example as the Boley lathe described in pars. **282—3**; but as a rule these accessories are not met with in the common modern turns; they only exist on lathes of rather large dimensions and are heavily made. Thus many practical men will doubtless for some time to come be under the necessity of themselves making these additions and of adjusting them on an ordinary pair of turns. In such a case either of the following plans may be adopted:—

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First method.—Make a pattern in wood (a well-selected piece of pear-wood is as good as any for this purpose), and in forming the hole for the bar, it should be made rather smaller than will be required, increasing the height by the space requisite for the tongue; send this pattern to the brass-founder, who should employ a rather soft brass that can be somewhat hardened under the hammer. Dress up as well as possible the four internal faces of the hole for the bar, and, in order that they may be flat, pass a file backwards and forwards on each face. Then, fixing this file by its extremities, work the poppet-head along it with the several faces in turn resting on the file. The pradel referred to in article **225** can be adapted for the purpose.

The most important adjustment is that of the two faces that slide against the sides of the bar, and if they are found not to be parallel, hammer carefully the sides the poppet-head at the parts where the hole is too large. By such means the adjustment of these faces can be made with sufficient accuracy without much trouble. The correcting of the hole in regard to height is easy, for a few strokes of the file in excess can be made up for by using a tongue of somewhat increased thickness.

When the hole is accurately fitted, and the screw and tongue in position, the poppet-head is placed on the bar of the lathe after displacing *p* (fig. 6, plate II.). A centre carrying a short, carefully-centred drill is substituted for b^1, and, after marking the new poppet, it is drilled to a considerable depth, that is to say about half way through; after this it may be reversed and a fresh hole drilled to meet that first made; a broach is passed through the hole thus made, and after it has been removed, the hole is finally enlarged by means of a specially-formed runner that accurately fits the headstock, p^1. It is formed at the end into a semi-circular drill, *b* D (fig. 2, plate V.), which both increases and smooths the hole, being driven by a pulley fitted on to its free end against the point of which a piece of wood is pressed. If

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these instructions are exactly followed we may be certain of ensuring that the hole in the new poppet-head will accurately coincide with the axis of the lathe. (See also **709**.) A similar method may be adopted when it is desired to form a conical hole with a tapered drill.

266. *Second method.* — If a watchmaker cannot conveniently obtain the rough brass casting he must prepare two strong plates of good brass, *c*, *c* (fig. 8, plate III.), accurately planed on their surfaces, and another piece, *b*, of rectangular section, the two faces of which are parallel and the thickness the same as that of the bar of the lathe ; then form the lower part of the poppet-head like a tenon of the thickness of the bar. Having set the several parts in position, as shown in the figure, drill two or more holes according to the size, in which solid iron or steel bolts are fitted. Placing the poppet-head on the bar of the lathe, the tongue and the piece, *b*, are fitted into their places, and, while so situated, the holes through *c b c*^{1} can be adjusted so as to prevent all shake, after which iron or steel bolts are fitted, as in the upper joint.

Removing the head from the lathe these bolts are filed almost flat with the surface and riveted. Afterwards it will probably be needful to pass the file through in order to allow the bar to enter.

The rivets should fit firmly, but without the application of much force ; as otherwise there would be a danger of altering the form of the hole. To secure an equal degree of rigidity the poppet-head made in this manner should be somewhat heavier than when cast. The upper portion will be finished as explained in par. **265**.

HOLLOW MANDRIL, PERFORATED TO RECEIVE CHUCKS, &c.

267. A serious difficulty is often experienced by practical men when they attempt to perforate longitudinally the arbor

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of a headstock; that is, in preparing it to receive the chucks. Whether we drill by the lathe or by hand, it is difficult when going to any considerable depth to obtain a tube that is exactly round and true internally. The difficulty can be overcome as follows, it being observed that the steel spindle must first be very carefully annealed (**76—8**):—

First method.—Rough out the arbor, leaving it of a greater diameter than it is finally required to be, and, having adapted a ferrule to it, set it up in the lathe (fig. 5, plate II.), supporting its nose in a hole of the cone-plate (fig. 4), which must be set accurately in the axis of the lathe. Put the poppet-head, *p*, fig. 6, in position, and replace its centre by one of special construction for holding drills, taking care that the drill employed is smaller than the hole is finally required to be. Drill the hole, examining it from time to time in order to make sure that no hard button is forming at the bottom. In case one does so form, it must be removed by means of a rod that is rounded at one end, cut like a file and hardened (see article **340**); the drilling is then renewed. If the button again forms, it is again removed, and the arbor is taken from the support and held by hand against a rotating drill. When the required depth has been attained, the hole is enlarged while holding the arbor in the hand against a semi-cylindrical drill in a lathe. The tube is then smoothed with a broach which enters without play to the bottom, its point being first broken off and the end sharpened to a very obtuse-angled chamfer. Proceed in the same manner, gradually breaking more and more off until the tube has the required diameter, and is sufficiently smooth.

Now take a taper arbor that runs very true, and adjust this in the hole as far as possible. It should have a good hold throughout, but more especially at the top and bottom. If the drilling has been true, that is to say in the direction of the point on which the new arbor turns, the taper arbor adjusted in the hole as well as its ferrule will all turn true.

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If such is not the case, the point at *n* (fig. 5) of the perforated arbor must be re-made until the desired object is attained. Then give the final form to the point *n*, and to the neck that is turned near this point and round the tube *g*.

268. *Second method.*—Take a piece of round steel of a diameter greater than the arbor is required to have, and a third or half as long again as the perforated portion. Drill through its entire length, commencing at either end and meeting in the middle. Broach the hole out true, and turn the steel so that its external surface is concentric with this hole and its extremities quite flat.

Now take a second piece of steel and turn it true, forming at one end a large pivot of such a diameter that it will just not pass into the smaller end of the tube already made, and about a quarter of its length.

Heat the tube almost to redness and, placing it upright on the anvil with the end at which the broach entered downwards, drive the pivot (after removing its point) into the smaller end of the tube; this second piece of steel of course not having been heated. When the whole is cool, the union will be such that the two pieces (as *c* and *h* of fig. 5, plate II.) are as firm as if made of a single piece of steel, providing the diameter of the pivot has been sufficiently great.

The cannon portion ought to be rather thick, and should not be raised to a too high temperature on account of the risk of distortion in driving the pivot into its place.

When the arbor has progressed thus far, it may be completed in the manner explained under the first method.

FORM OF BEARING POINTS AND SHOULDERS.

269. When the nose of the arbor is cylindrical, a good form to adopt for the bearing shoulder is that shown at *a*, fig. 4, plate III. Some prefer to make the portion *a c*

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conical, but then, in order to prevent the cone from jambing in the headstock, it is essential that the portion *a* be so curved as to answer the purpose of a shoulder. A few trials, applying pressure lengthwise at the point *b*, will enable a workman to decide on the most convenient form of bearing so that the arbor shall turn without play and yet freely—in other words, with the least possible resistance and without rapid wear.

The best form of point and of hole to receive it are indicated at *b* of the same figure. They have been determined experimentally, and it is asserted that they will maintain the oil on the rubbing surfaces for the greatest possible length of time.

CHUCKS—THEIR ADJUSTMENT.

270. In fig. 4, plate III., at T is represented one of the most commonly used chucks for turning pieces that can be fixed by means of shellac or sealing wax on a flat surface. They are also sometimes made with two or three screws on the plate, by which a circular cutter, wheel, index, &c., can be conveniently centred. Others again do not carry a plate, but are terminated with a truncated cone (indicated by dotted lines in the figure) in the axis of which a hole is drilled and tapped. A series of such chucks will constitute an efficient substitute for the screw-head tool; for when a screw is screwed into the chuck, one can turn it, diminish, smooth and polish its head, &c. And two other kinds may be made; a series for taking drills and a series provided with a plate and projecting screw on which is a nut with cone-piece, to be used in place of the common screw arbors, indicated in fig. 4; of course, if the lathe is driven by the right hand, the thread will require to be left-handed.

If a chuck is removed from the lathe and then replaced, it is nearly always found that the object attached to it is slightly out of truth. Such irregularities can be nearly,

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if not quite, avoided by observing the following precautions:—

(1.) The shank that passes into the arbor must be long enough.

(2.) A guide pin is let into the nose of the arbor so that the chuck always occupies the same position.

(3.) The shoulder of the chuck fits exactly against the end of the arbor.

(4.) And lastly, a condition that is very essential, the shank must only fit closely at the shoulder through a length of one or two millimetres ($\frac{1}{16}$ inch), and throughout the rest of its length, especially where it is clamped, it should fit easily but without play.

Objects that can be finished without removal from the wax chuck should, if possible, be turned in a lathe in which the front bearing of the headstock is divided, so as to allow of the mandril, with the chuck still attached, being removed from its seat: it can be then again restored to exactly the same position. This cannot be done when the chuck alone is removed and replaced. A variation in its position will often be occasioned, owing to a greater or less degree of pressure being applied, or to particles of dirt getting between it and the shoulder, &c. Such an inconvenience is especially noticeable when using screw-on chucks; and it is always necessary, if accurate workmanship is looked for, to pass the graver over the wax face each time it is replaced on the mandril nose. (See article **461.**)

Chucks with conical tails, when the precautions indicated above are observed, are more exact than those with a screw.

ON DRIVING WITH A FLY-WHEEL.

271. The lathe fitted with the various accessories above described can be driven, if desired, by a bow; but with both this lathe and the several kinds subsequently considered, there is generally a marked advantage in replacing the bow

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by a fly-wheel; and this advantage is so obvious that it becomes a matter of surprise why watchmakers have not long ago recognized the benefit engineers derive from its use. While these latter are careful to profit by every advance that is made, the former as a rule still adhere to their ancient bow, which, for a vast number of operations, involves a great amount of labour with no counteracting advantage. For example, to turn a barrel arbor out of solid steel will occupy a man for a whole day on the old system, whereas, if provided with a lathe driven by the foot, he can make it in about two hours.

The objections raised to the latter are :—

Increased cost; greater amount of space required; and the hand is said not to possess the same delicacy of touch.

The first objection cannot be entertained when we remember how great an economy of time is effected.

The second is of no moment, as will be gathered from the following account of the various arrangements of fly-wheel that can be adopted.

The third is also unfounded for the great majority of cases; but we do make certain exceptions. For a period of four years we worked side by side with a Swiss workman engaged in planting escapements, who turned and polished his pivots in a lathe driven by a foot-wheel, and it cannot be said that he had more accidents than the other workmen.

It is merely a question of practice, and skill in its use is less difficult to acquire than that of the bow.

We strongly recommend every watchmaker to arrange a large size foot-wheel if possible, but, if the arrangement of his bench renders this impossible, he should at least provide himself with a hand-wheel; it cannot fail to prove of the greatest service to him.

272. Hand turning-wheel.—This may be fixed either on the bench or below it.

Fig. 6, plate III., representing a hand-wheel carried by a bracket fixed to the bench, hardly requires explanation.

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It will be seen that the axis of the fly-wheel rotates in a slide, *i*, which can be moved backwards or forwards so as to secure the requisite tension in the cord; and the entire arrangement can be turned back to occupy the position

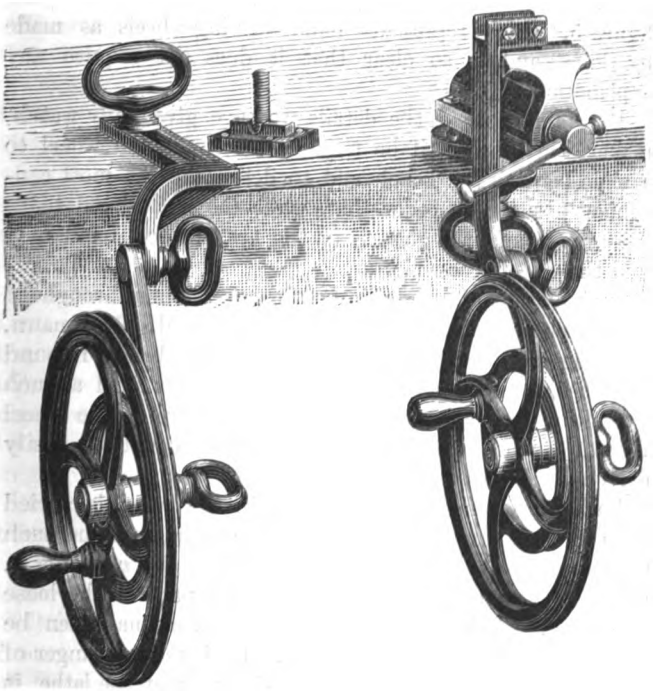

Fig. 5.

indicated by dotted lines, and thus leave the front portion of the bench free when the wheel is not in use.

Such an arrangement is useful for rotating a cutter, slitting screw-heads, &c., but, for turning with a graver, the wheel supported on the bench is less convenient than one under the bench in the position indicated at *n s*, fig. 7, plate III.,

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for it necessitates the left arm being constantly held up in the air. The wheel may be carried by an arm screwed to the front of the bench and projecting downwards, or by a similar arm made to clamp in the vice together with the lathe. Both these systems are shown in the accompanying figure 5, which represents hand turning-wheels as made by Boley, and is so clear that it does not require any explanation.

By taking note of the details we have given, any watchmaker will be able, if he requires it, to adapt a wheel to a slide beneath the bench and to determine the most convenient position in order that, while the right hand holds the graver, and the glass is in the eye, the left hand may find the wheel accessible.

Such a system has been in use for a long time throughout the watch manufactories of Saxony, and M. Grossmann, referring to it, writes as follows: "At each bench I found a small hand-wheel about 9 inches in diameter fixed at such a position in regard to the vice (the centre of the wheel about 16 inches below the lathe) that it could be easily driven by the left hand."

Lathes are sometimes made in which the wheel is carried on a bracket fixed to the bar of the lathe in some such manner as that indicated by dotted lines at *z v x y*, fig 6, plate III., of this bracket may form a part of the loose headstock. This headstock and the wheel may then be removed and replaced as required. If there is a danger of the weight of the wheel causing a vibration of the lathe, it must be supported by a long screw in the bench, or by a prop, as shown at *s*, fig. 6.

It should be observed that such an arrangement demands a certain lightness of construction, and it is a good plan to add a screw for advancing the fly-wheel along its slot, *i*, so as to avoid a jerk when adjusting the tension of the cord.

273. Of course it will be understood that, in delicate work, the cord must be very lightly stretched; thus, in the

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case of thin objects, its mere rolling over the ferrule without any true driving, the tension being almost nothing, will often suffice to give all the impulse that is required.

In conclusion, it may be pointed out that, before coming to a decision, the watchmaker should try the wheel placed both above and below his bench. Neither the diameter of the wheel nor of the path described by its handle is a matter of indifference; the whole should be well adapted to the hand of the workman. Remember that dexterity, facility, and lightness of touch vary with the individual, and that, whereas one man finds he can work better with the elbow of his arm that drives the wheel resting on the bench or on some projection from it, another will prefer to hold the entire arm in the air.

The wheel must be so arranged that the body and the arm are not only not constrained but are firmly supported; the action of the graver will then be thoroughly safe. When the wheel is placed below the bench, the handle is sometimes replaced by a small treadle, on which the left hand presses to communicate the impulse to the wheel, while the right, firmly resting on the bench, holds the graver.

Many of the above directions are equally applicable when the foot-wheel is used.

274. Foot-wheel with treadle.—One form of this is shown in fig. 7, plate III.

Before proceeding farther, and in order to make the remark once and for all, we would point out that most of the appliances described have been selected with the view to affording the watchmaker the most economical arrangements, as well as designs that can be easily fitted up at a distance from manufacturing centres; we shall give specimens such as any one can, without difficulty, make and modify according to his requirements or his taste.

The large driving-wheel, R, fig. 7, plate III., is usually set in a plane at right angles to the wall against which the bench is fixed; that is to say, in the position indicated at

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q m. This is very convenient in working, because the knee of the leg that treadles can be brought against the wheel at any moment and so arrest its motion instantly.

When there is insufficient space the wheel may be in a plane parallel to the wall, and the cord will then have to pass under a guide pulley, *c*, fixed to the under side of the bench E. By this means the motion of the distributing axis *f d* is the same as it would be if the wheel were at *q m*. It is needless to add that, when the wheel is in this latter position, the pulley *f* must be fixed to the arbor at a point just above the wheel; that is to say, to the right of *d*.

The wheel may be simply carried by a strong bolt fixed in one of the uprights of the bench.

For work that does not require the application of much force, the weight of the wheel should be moderate; but for driving a lathe that is intended, say, for clockwork, a certain amount of inertia is essential. In that case, a cast-iron wheel should be used similar to those often kept by ironmongers.

275. The foot-wheel may be poised so that it rests in any position on its axis, in which case it will in general require to be started by hand; but some attach a weight to it in such a position that, when at rest, the wheel is as far as possible from the dead centre. When this plan is adopted the wheel can in all cases be set in motion by the mere application of the foot to the treadle.

The treadle represented in fig. 7 is a board, to the front of which are fixed two pins forming pivots that work in two cubes fixed to the floor. A strong hinge is sometimes used, and other arrangements will suggest themselves. (See also fig. 6, page 188.)

276. Arrangement of the distributor or guide pulleys.—The axis of the distributor, *f d*, fig. 7, plate III., must not be too thin, as it would then be liable to vibrate; nor should it be too thick, as in such a case there would be a useless resistance opposing motion. It will be found con-

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venient to make the triple pulley *d* of such a diameter that, by placing the hand against it, the motion of the axis can be instantly arrested. When this is done the large wheel R will continue its rotation for an instant in virtue of the momentum acquired, but the cord will slip over the pulley *f*, without being allowed to cause *f d* to revolve.

The uprights *a* and *b* that support the axis are usually made of metal ; but if they are not very thick or set sideways with the greatest dimension in the plane of *f d*, their elasticity is very inconvenient.

The arrangement shown in fig. 7 is simple and economical, and it has been successfully adopted in practice. On the board E two wooden cones *a* and *b*, perforated throughout their length, are fixed by means of long bolts screwed under the bench by two strong nuts. In the head of one bolt is fitted a centre to take one end of the arbor, and the other end is carried in the extremity of a screw with locking nut that is screwed into the head of the other bolt.

As the wood is thus set upright and very firmly fixed, it will possess no elasticity, and the system is firm and solid.

277. A good form of distributor, made by Boley, may now be seen in many of the tool-shops : in conjunction with the fly-wheel that accompanies it, it affords a very convenient source of power for watchmakers. Both are shown on a small scale in figure 6 on page 188, representing a work-bench, half of which is cut away in order to make the complete arrangement evident. The axis of the distributor, carrying two cone-pulleys, is supported in a U-shaped frame that is capable of moving about an axis parallel to that of the pulleys, and can be clamped by a nut in any position. The bed that carries this frame is fixed to a vertical pillar which can rotate or move up and down, and is fixed in position by a clamp. The foot-wheel differs from those already described in having only a single cord to the treadle. This cord passes round a barrel containing a clock mainspring and provided with a click that engages

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with a ratchet on the fly-wheel axis. On depressing the

Fig. 6.

treadle, the spring is wound up, an impulse being at the

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same time given to the fly-wheel: the uncoiling of the spring serves to raise the foot. It will be gathered from the above brief account of the distributor that the tension of either band can be modified as desired, and, by turning the spindle round the vertical axis, a band may be led to a lathe or other tool not directly opposite to the distributor.

THE CORD AND TENSION-PULLEY.

278. The cord which transmits motion from the fly-wheel to the pulley of the distributor is always at the same tension; its length may then be adjusted from the first so as to communicate the motion efficiently. But such is not the case with the cord that passes from the pulley *d*, fig. 7, to the lathe. This latter must be tight or slack according to the dimensions, &c., of the work in hand; moreover, if the ferrule is not fixed concentric with the object that is being turned, or if the pulley *d* is not true on its axis, the cord will be liable to hold and to slip alternately.

This inconvenience can be avoided, and the tension of the cord maintained constant and sufficient by using the tension-pulley.

It is made in various forms; that shown in fig. 1, plate III., will give a clear idea of the principle and mode of action, and other devices answering the same purpose will suggest themselves.

Close to the distributor or somewhere in the direction of its axis, as indicated in fig. 1, a lever with two arms is centred on pivots. Its bent arm *c* serves as an axis for a small pulley, *j*, very light and turning freely; the other arm *d* carries a heavy mass that will slide along *d*, being held by friction in any position.

The mode of action will be obvious; the cord from the distributor *m*, to the lathe, *n*, passes over the pulley shown at *c* and *j*, and this pulley under the influence of the weight *d*, will stretch the cord and always maintain it at the same

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degree of tension, which can be adjusted as required by varying the force, in other words by bringing the weight *d* towards or from the centre of motion of the lever. Slight irregularities due to the excentricity of the ferrule *n* in the lathe or of the pulley *m* of the distributor will then produce no ill effect. The tension of the cord, moreover, can always be adjusted so that it is proportional to the delicacy of the work.

279. In lathes of large size, the cord is frequently passed quite round the tension-pulley, by which the influence of this latter on the force exerted is increased; in the ordinary arrangement of the cord it is necessary to take note of the direction in which the cord is travelling.

If it is from *n* towards *m*, fig. 1, plate III., the action of the cord is found to be more marked than when it travels in the opposite direction. In the former case with a suddenly increased resistance the friction-pulley would give way a little. The watchmaker must decide for himself whether the upper or lower cord shall be stretched; or if it is worth while to cross the cord, as shown in fig. 1, either with a view to change the direction of motion or to secure a greater amount of adhesion of the cord on the pulley.

280. Joining catgut bands.—In delicate turning with the hand or foot-wheel it is important that no jerk should be communicated to the work when the joint in the band passes over the ferrule or the pulley of the mandril; such a jerk can only be avoided by a carefully-made joint. Several methods are adopted; for bands of large and medium size it is best to use the steel hook and eye screwed on to the ends of the band, these ends being first tapered with a knife and their ends burnt with a hot wire to cause an expansion that will prevent their drawing away from the screw. But such attachments cannot be used with bands under 1-16th inch in diameter, and one of the following methods must, therefore, be resorted to.

(1.) The most expeditious is a simple knot, and the

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weaver's knot is by far the best, as it permits of the ends being cut off close, and stands out to nearly the same distance all round the cord. A careful inspection of the annexed figure 7 will enable any watchmaker to make it; he

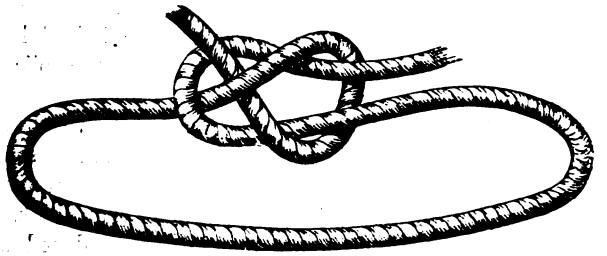

Fig. 7.

need only observe that the lower portion, representing the length of lathe-band, must be somewhat less than is ultimately required, and the knot is to be tightened by drawing the two free ends, while the first point at which the cord crosses is held between the thumb and first finger. The ends must be cut off nearly to the knot, then gently singed to cause their expansion, and the knot rolled between the finger and thumb in a little beeswax.

(2.) The ends may often be spliced together, and, although this occupies more time, it has the advantage of producing a gradual increase and decrease in thickness, so that all jerk is reduced to a minimum. The following method is given by Holtzapffel. Having stretched the band, measure off a length greater than is required for the lathe, and make transverse holes through the catgut at two points rather nearer together than the measure of the lathe (to allow for further stretching). Pass each end through the hole in the other and draw tight; pierce two more holes at right angles to the first and just above them, again passing the ends through from opposite sides of the band. Unravel the free

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ends, cut away about one-fourth of their substance by a sloping cut from the inner side next the splice; re-twist and again pass the ends through holes transverse to the last and pull tight. Repeat this operation several times, gradually reducing the thickness of the end, until the very fine ends, after passing through their holes, may be cut off close. Hammer the finished splice all over gently; indeed hammering may be resorted to at intervals during the splicing, in order to secure an even surface.

(3.) A simple substitute for the hook and eye that is sufficient in the case of fine bands not subjected to severe tension, may be made by twisting a fine steel wire into a close spiral, rather less in internal diameter than the band, and about half an inch long; it must be hardened and tempered blue. Slightly taper each end of the band, and screw first one and then the other each half way into the spiral, taking care before screwing the second end to put a sufficient amount of inverse twist into the band itself. The direction of the spiral must be such that the catgut does not unravel in screwing, and the strength of the joint may be increased by carefully heating the coil to expand the ends of the band.

IMPROVED FORM OF TURNS.

281. It cannot be denied that many of the turns which are in the market, whether they be of English or foreign construction, leave much to be desired as regards their adjustments, and the reduction in the price of this invaluable tool is generally more than neutralized by its deficiencies in this respect.

Several manufacturers have recently endeavoured to remedy this particular want, and we would draw special attention to the turns and small lathes designed by M. Boley, of Esslingen (Germany), as they are remarkable alike for accuracy of construction and adaptability to the many wants of the watch-jobber and repairer. He has

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already been referred to above, and other tools of his construction are mentioned in the course of this work.

282. A special feature in these turns is that, although in their simplest form they are no more elaborate than an ordinary pair (fig. 6, plate II.), the same frame can receive any one or more of a very great variety of additional pieces, adapting it to perform any operation for which its weight and height of centre is fitted; this fact is sufficiently evidenced by the three figures 8, 9 and 10, on pages 194, 196, and 212 respectively. But even in its simplest form the tool is characterized by several novel features. The rectangular bar hitherto in almost universal use for this class of lathe, and shown in fig. 6, plate II., is replaced by one of triangular section, a very important modification as the parallelism of the runners, when the movable poppet-head occupies different positions, is rendered far more secure. The risk of irregularity in this respect is still further diminished by the excellent arrangement adopted for locking the runners in place of the well-known bolt and side-screw. A V-shaped slot is cut longitudinally in the head of each poppet-head, of such a size that the runner, when lying in it, projects slightly above the top. The steel plates, seen in fig. 12, can be brought firmly into contact with the runners by means of the saddle passing over each of them, which is depressed by means of a bolt provided with two hard steel cones facing each other, and a milled headed nut (seen at the back). By such an arrangement the bending action of the ordinary nut is entirely avoided, the top of the poppet-head is left free, and the initial adjustment of the runners in right line is much facilitated.

Arranged as a simple pair of turns, the tool is provided with the runners already described in this work, some of which are represented in plate II., and there is an adjustable friction pulley carried on a slide for taking off the pull (when turning with a wheel) from delicate spindles, as is done by the pulley K, in fig. 18, par. **492.**

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283. A lathe specially intended for drilling and counter-

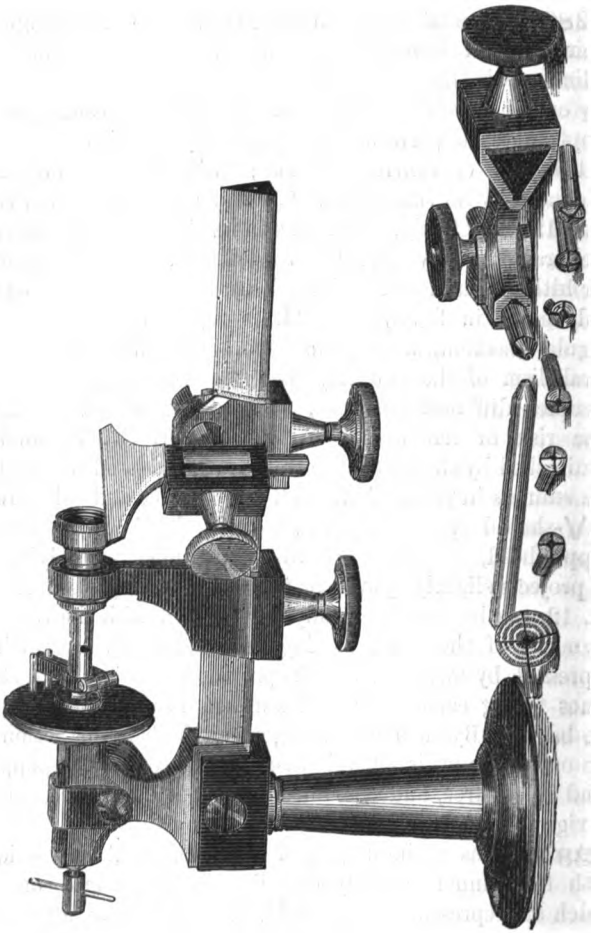

FIG. 8.

sinking, and built up on the same bar, is shown in fig. 10, on

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page **212.** The drill being centred in the six-screw chuck, or in a special chuck substituted for it, the object to be operated upon is held against a flat table at the end of a runner in the loose poppet-head, and pressure is applied by the lever while the drill revolves. It will be evident that the same arrangement would take the place of fig. 5, plate II., if necessary. (See also article **443.**)

Fig. 8, on page 194, shows a headstock perforated to receive the American split chucks which are now very commonly used. The chucks are of two forms; those for taking spindles, arbors, drills, &c., and the step chucks for centring discs, wheels, barrels, &c.; both kinds are shown in the figure. A rod passing through the mandril from the left-hand end is screwed into the thin end of the chuck, thus drawing the latter against a conical seat in the nose of the arbor, at the same time closing its three jaws on the object placed between them. This nose is also tapped externally so as to receive chucks of the ordinary form. It will be observed that the T-rest is clamped in the manner already explained in **252.**

Fig. 9, on page 196, represents the only other of the many forms of this lathe to which reference will be made. It will, however, be better understood after reading articles **382—7,** on the universal mandril, as it constitutes a complete small-size mandril with pump-centre, slide-rest, meeting-centre, and all the special features of that well-known tool.

LATHES WITH REVOLVING MANDRIL.

284. To adapt the ordinary turns.—These lathes are often specially arranged for the manufacture of a number of similar objects, such as screws (see article **441**), and are complicated by the addition of pieces that would be of no value to the ordinary watchmaker. One feature that usually characterizes them may, however, with advantage be

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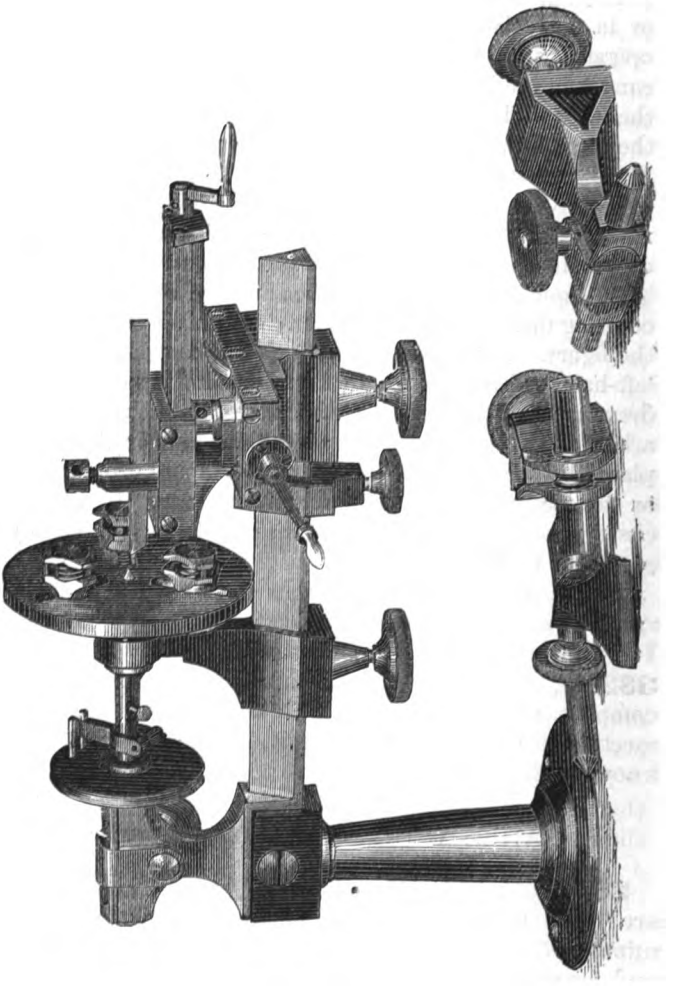

FIG. 9.

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considered, and it would be a useful addition to make to the turns figured in plate II.

In fig. 2, plate III., P is a U-shaped headstock, made of separate pieces united by screws or rivets, or, preferably, from one piece of metal; it is fitted to the bed of the ordinary turns and takes the place of the movable poppet-head *p*, in plate II. The fixed poppet-head is shown in dotted lines and carries a centre, *h*, the use of which will be presently explained.

The two branches of P terminate in bearings with covers screwed on, in which the arbor A rotates.

This arbor is hollow throughout its entire length as indicated by the more distant pair of dotted lines. The pulley to which motion is communicated is fixed at the left-hand extremity, and at the right hand is a disc or plate, *r d*, seen in front elevation at *l d*, that should be somewhat massive and is formed of two pieces *r* and *d* united by screws. The thicker piece, *l d*, has a rectangular opening cut through it, the two longer sides of which are sloped from without inwards, so that a section perpendicular to the plane and through the dotted line will show the aperture of a dove-tail form.

Two accurately fitting dies, *c*, *c*, are held, friction-tight, between the plates *r* and *d*; they are movable along a diameter and an object placed between them can be firmly clamped by means of the screws that are against the dies.

285. The following method is adopted in order to ensure that the hole, which is bisected by the line of junction of the dies, corresponds exactly with the axis of A. The centre *h* (in the fixed poppet-head of the turns), which is directly opposite to the axis of A and must be carefully adjusted, is provided with a semi-cylindrical drill similar to *f*, but somewhat larger. This drill must have been turned with the runner *h*, so as to be true with it; in that case the dies will be perforated exactly along the axis of A.

When the hole has been made, and broached out if

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needful, it is evident that a rod clamped between the dies can only be excentric along the diameter at right angles to the dotted line *a f*, and it will thus be easy, with the two screws, to set it in an axial position.

The pulley may be placed at *i*, but this is inconvenient except when the bow is exclusively used; when turning with the wheel, it is often better to adopt the position *b*, as the cord can then be put on and off.

286. The mechanism above described is useful for very many purposes: thus a rod, *b a*, can be adjusted with the requisite amount of metal projecting at *a*, and screws, drills, taps, set-hand squares, clock studs, &c., may be rapidly roughed out, especially if the motion is continuous. As the extremity *a* can be quickly reduced to any required dimensions, it becomes a convenient chuck for centring a watch-hand when the tube requires to be diminished in its external diameter, a minute-wheel that is too high, or the teeth of which require to be topped, &c.

Lastly, in such a tool cannon pinions, tallow-drop heads, cylinders, plugs, &c., can be quickly roughed out. For example: bring the drill *f* up against the rod *a*, which must not project more than is necessary, and drill a hole; then, replacing the T-rest, turn the end and surface and cut off to the required length, and a cylinder shell is neatly and promptly made. A number of such shells can be prepared in a very short space of time.

It is important to observe that if the rod *a* projects too far, the flexibility will prevent its being turned cylindrical. When a considerable projection is essential, mark a centre with the drill, and replace *h* by an ordinary pointed centre, that must be perfectly true. It will be easily seen that, if both centres are not rigorously true, no good work can be done.

These explanations will suffice to enable any watchmaker to make good use of such a tool.

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LARGE-SIZE LATHES.

287. The ordinary turns provided with the several accessories hitherto described and represented in figs. 2, 3, 4, 5, &c., of plate II., and figs. 1, 2, 4, 6, 7, &c., of plate III., must be regarded as a small-size lathe suitable for fine work and fairly complete; but it is not sufficiently massive for making the plate of a watch or most of the parts of time-pieces.

A lathe-head twice the size of that shown in fig. 10, plate III., will serve for nearly all purposes. As it will take chucks of all sizes, spindles of considerable diameter, laps, large circular cutters, small emery wheels, &c., the variety of uses to which it can be applied will be obvious.

To make such a tool, the frame of a drilling tool, to be met with in tool-shops, can be utilized, although its arbor cannot be made available. In the absence of such a resource, it is easy to make a wooden pattern and obtain from a brass-founder a frame similar to B, fig. 10, plate III.

After filing all its surfaces square, mark, on the outer surfaces, the positions of the holes for the bearings, and partially drill them with small-size drills, in order to avoid displacement, and then drill from end to end in the manner subsequently explained (**709**).

288. If only a small pair of turns is available the operation can be conducted as follows: Support the frame B between the centres with their points in the holes already partially drilled; then replace one of these centres by a drill-carrying centre (as shown at *h*, fig. 2, plate III.) that is set in rotation with a ferrule at the farther end. While one person works the bow or driving-wheel and presses against the outer point of this centre in order to make the drill (which must be somewhat large to avoid flexure) bite, the other supports the frame, turning it through a quarter of a circumference at intervals. When the hole is through, reverse the frame and drill the other side.

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Slight differences can be corrected by means of two centres that are formed into broaches at their ends and act together. Finally, if this method is not sufficient, any irregularity that remains may be corrected, before the covers *f, f,* are fitted, by using a temporary arbor formed of a cylindrical rod somewhat larger than the holes, which should be roughed at its ends by drawing the edge of a file over the surface lengthwise. The arbor having been set in position is caused to rotate and the covers are gradually screwed tighter until fully home.

A smooth cylindrical rod with oilstone dust and oil can also be used in a similar manner. Emery should not be employed for such a purpose as it is apt to leave particles embedded in the metal, which cause wear of the arbor.

The above explanations will doubtless be more than sufficient to enable the reader to prepare such a headstock.

289. To make the arbor and its accessories.—To drill a steel arbor from end to end that is at least twice the size of *m* A C, fig. 10. plate III., is a long and difficult operation for a watchmaker; but, if he somewhat increases the proportions, he may make it of the best iron tubing, that can be obtained from metal merchants.

An arbor that is drilled throughout its length is certainly preferable; but, if the workman is willing to give up this advantage, he can use iron tubing for the body of the arbor only, and he should select it very thick. Drive the steel point *x* to some distance within the tube, and at the other end insert a steel tube, *n* C, tapped internally and externally at C, and having at *n* a projecting ring that is left when the steel is shaped in the lathe. The adjustment of these pieces is effected as explained in par. **268**; the two steel pieces being driven cold into the heated tube.

The external surface of C must be tapped very carefully with screw dies (although cutting in the lathe, if this can be done, gives still better results), and afterwards a series of screw taps must be made exactly similar to C, except

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that they are faced on four sides throughout a considerable portion of their length so as to give cutting edges. After hardening and tempering (**84—91**) they will serve to tap the inside threads of chucks to fit the arbor.

As regards the interior of C, which is seen in end view at S, it is tapped, also with the greatest care, with a thoroughly good and sharp-cutting slightly conical tap, which should be longer than the usual form. That is to say, it should have a portion in advance of the tap, gradually tapering to the point, where a small flange is formed a little less than the inside of the tube A. By taking this precaution the tap is compelled to travel along the axis of the tube and the thread is cut both quicker and better.

The tap employed should correspond with one of the holes in a large-sized screw-plate (or a set of dies); for subsequently the tangs of the chucks, as T, will require to be fitted to S. (See the articles on taps and dies **423—440**.)

290. Chucks. — These may be divided into two classes :—

(1.) Those that screw into the head C (at S), which are solid and usually have one of the three forms shown at T, fig. 10, plate III., and indicated by the letters *a a*, *e e*, *i i*. They may have, at the centre, a screwed or taper arbor, which, however, must be very short.

(2.) The second class comprises those that screw on to the nose, C, of the mandril arbor, which must, of course, be hollow at their centre. Two forms are commonly used : one is shown by dotted lines at *g g'* and the other at D. This latter is also represented in front elevation at D^1. The diameter of the plate or ring *g* may vary between that of *n* and nearly twice the height of the centre from the bar.

Each chuck is drilled perpendicular to its axis with a hole, shown at *v* and at D. This is intended for the introduction of a rod or "tommy," which can be used as a lever for

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screwing or unscrewing the chucks on the nose of the mandril.

It is needless to explain the mode in which the chuck D, also seen at D^1, is used: after reading articles **284—6,** it will be very evident that it will adapt itself to a great variety of every-day work.

The American "scroll" chucks that have come into general use in recent years for larger lathes are very convenient substitutes for this form of chuck, and lend themselves to many other uses for which it is not available. In them the trouble of adjusting the screws is avoided as the three "dogs" are advanced together by means of a key; they can, moreover, be used to grip an object, either internally or externally, of any diameter between limits determined by the size of chuck. The ordinary form must not be relied upon where very exact centring is requisite, but many operations will suggest themselves to any workman in which such absolute accuracy can be dispensed with. For some details in regard to split chucks, see article **283.**

At A, fig. 1, plate V., is represented another form of chuck that screws on to the external thread on C. This chuck has, at its centre, a projecting tapered wood screw, *x*, which must not be too long. Wood blocks can then be screwed to it for holding, for example, rings that have to be turned or polished; or, among other things, the cylindrical portion of a clock spring-box that has to be turned on its external surface, or requires the recess forming in which the bottom fits and is soldered, &c. (**568**).

291. When the lathe-head is completed and fixed firmly to the bench with screws, an adjustable T-rest must be constructed. Every watchmaker will doubtless be able to make it; nevertheless, a few details may be acceptable.

A thick tube, *c*, of sufficient length, in which the rest is fitted, must be firmly riveted or brazed to a strong plate *b a*, fig. 9, plate III., having a longitudinal slit, *n*. A bolt, *d*, with a large flat head, passes through this slit and through

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a second cut in the bench on which the plate rests, so that this latter can be clamped in any position by a nut at the end of *d* that has a bearing against the under side of the bench.

As *b a* is cut throughout its length, very considerable variations can be made in the position of the rest, even with a comparatively short slit in the bench.

The tube *c* must be of such a height as to permit of the necessary vertical displacement of the rest, and the plate *b a* may, if preferred, be raised on a disc or block traversed by the bolt.

292. Lathe support.—When turning with the foot-wheel it is often found convenient to support the lathe on the bench itself instead of in the vice, so that the two arms can be supported by the bench. This can be easily effected by using a slide with movable jaws, as shown in fig. 10, plate V.

The plate *a b* is slit almost throughout its length for the passage of the bolt, *v*, so that it can be moved backwards and forwards at will. This plate *a b* carries a fixed jaw, *d*, to which a second movable jaw, *c*, is attached with a screw: the shaded block enclosed between the two represents a vertical section of the tail of the lathe-bed. The drawing is sufficiently clear to render further explanation unnecessary.

Evidently, if there is sufficient height to spare, a vice fixed at one end of a slide, such as *a b*, will answer the purpose.

293. Slide to carry rests, &c.—Some tools intended for special purposes, which will be subsequently described, involve the use of a slide on the bar of the lathe. It will be found easy to make a slide that can be adapted to carry anything, especially if the form shown in fig. 11, plate V., be adopted.

A block of brass, *r s t*, which is cut away vertically to admit the bar, is traversed by a round hole in a horizontal direction, and at right angles to that which receives the lathe

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bar; through this hole passes the slide of the rest. As the sliding piece thus rests on the bar of the lathe, the tightening of the screw *z* will clamp the entire system *r c s z*. The portion *r s t* can be made of three pieces joined by screws or rivets.

As will be seen from the figure, the sliding piece is a semi-cylindrical rod; it acts in precisely the same manner as the T-rest carrier of the ordinary turns. If it is required that the tool, when supported, shall be capable of taking a varying inclination to the right or left, *c r* should be left cylindrical and the hole drilled somewhat higher up, so that the bottom edge of the slide is on a level with the upper side of the bar.

294. Support for raising the headstock.—It is seldom that a watchmaker can afford to spare sufficient space for a large engineer's or an amateur's lathe; and even if he have the space, such a lathe is only occasionally of use to him, and he may well hesitate at incurring such an expense. The want of it can be made up for in the following manner.

This mode of supporting the free end of the lathe-bar secures, it may be observed, a remarkable degree of firmness, so that very heavy objects can be turned in an ordinary lathe when it is adopted; if such a degree of steadiness is not required, simpler methods, which will at once suggest themselves, will suffice.

Fix an ordinary lathe firmly, either by means of screws or in the jaws of a vice, so that it stands above the level of the workboard. To this board screw a dovetail guide, shown in section at A, fig. 6, plate V., underneath and parallel to the bar of the lathe. To this is fitted a slide P of such height as to receive the free end of the bar at *g*, where it must be clamped by the screw *f*. When the slide P is firmly held to its guide, the lathe will be very steady.

The slide is traversed through a portion of its height by a kind of bolt or key, *c d*, the conical foot *c* of which engages on the one side with the guide A, and on the other with the solid

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portion of the slide itself. The upper end, *d*, of this bolt is traversed by a screw, *nj*, having a conical stem from *n* to *i* and a thread from *i* to *j*. When *n* is tightened, the slide will thus be firmly fixed in consequence of the head *c* being drawn against the guide; and, on unscrewing *n*, the slide is at once released and can be removed altogether if not required.

TURNING WITH THE SLIDE-REST.

295. Brass is easily turned with the slide-rest in an ordinary lathe arranged for the purpose, or on a mandril; but the turning of steel demands rather more care in setting the cutter so as to obtain the best cutting edge as well as in determining the point of application of the tool.

Preliminary trials must be made, and the following remarks will be of service as a guide.

296. Engineers use a hooked tool to a very great extent for both planing and turning. Both experience and reasoning point to the conclusion that a tool of the form *b* or *d* (fig. 9, plate V.) possesses many recommendations, and numerous designs of hooked tools more or less resembling these figures are employed with advantage; the tool occupies the best possible position in reference to the surface it is required to cut, and the cutting edge is both sharp and solid. It will be evident that a certain relation exists between the cutting angle and the point of application of the tool to the cylindrical object that is being turned, and this it is necessary to determine. With a hooked tool, as with the ordinary slide-rest cutter, a cutting angle which is too acute will wear away rapidly; when too obtuse, the edge scrapes and will only act when considerable pressure is applied.

In conclusion, it is clear that in forming or re-grinding any tool for cutting a surface, it must be so arranged that its edge makes the least possible angle with the surface that is consistent with the securing of a sufficient degree of

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resistance to the cohesion and the hardness of metal operated upon; in other words, the end of the tool must be almost tangential to the circumference of the object, and the angle of the cutting edge must be obtained by removing metal from the top face of the tool.

These principles are applicable to all tools for metal; to the blades of drills as well as to the cutting edges of gravers, &c.*

297. The angle of the cutting edge of the tool used in the slide-rest for steel should be less than that employed for operating on brass. According to Holtzapffel, it may vary in the former case from 60° to 80° and, in the latter case, from 70° to 90°, according as the tool is required for rough turning or finishing. 60° and 80° may, however, be taken as convenient angles in the two cases respectively. Simple methods of ensuring that the cutting edge has any required angle are described in articles **396—8.**

The velocity with which the lathe revolves should also be less when turning steel, and care must be taken that both the tool and object are constantly moistened with oil or soapy water, &c.

It is sometimes desirable to arrange a small dropping-can for the purpose of keeping up the supply; this may be easily done by placing a can containing the fluid above the level of the work and allowing a piece of lamp-wick, previously moistened, to hang from it so as to almost touch the work: a continuous series of drops will fall owing to the influence of capillarity.

298. When roughing out work it is best that the cutter first travel perpendicular to the object, from *a* towards *b*, fig. 2, plate IX., and then in the direction of the arrow. The

* We would again refer the reader to Holtzapffel's *Turning and Mechanical Manipulation.* In Volume II. he will find a very important discussion on cutting tools, which, however, it would be impossible to usefully abridge.

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corner *a* should only be used for finishing an internal angle or for roughing it out, and, in this latter case, the cutter must advance along *a b* and be withdrawn from the metal in the direction of the arrow. The small face at the end, *a c*, should be narrow.

299. Ordinary slide-rest.—The slide-rest usually employed in a common lathe is made in the manner shown in fig. 7, plate V.: *c* is a "saddle" that fits on to the lathe-bar, and has a dovetail slide, *a a h*, at right angles to the bed. On the slide *h* is mounted at right angles a second slide, which thus moves parallel to the bed; it is seen in vertical section at *n p n*. This second slide carries a tool holder, *b d*, which can thus be caused to move backwards and forwards as well as sideways.

300. *Another system.*—A similar result may be arrived at when using a pair of turns by means of the following apparatus, which is very simple and easy of construction:—

Two solid angle-pieces, E, E (fig. 12, plate V.), filed up square, are united together, and pairs of holes are drilled through them at *a*, *c*, E, and *d*. Those at *a*, *a* must be of exactly the same size as the lathe centres.

When these holes have been carefully made, the pieces, E, E, are fixed to a base, B, and the cylindrical rods, *c c*, *d d*, on which the tool-holder *p b* slides by the action of a screw *v*, are fixed in position. The hole at B has the same diameter as the upright portion of the T-rest.

An examination of the figure will at once make clear the manner in which this appliance acts. The two lathe centres are passed through the holes *a*, *a*; through B passes a short rod to replace the ordinary vertical rod of the T-rest. After clamping the screw, *z*, the whole will be found to be firmly fixed; if it is required to secure a greater degree of steadiness, clamping screws may be placed in the positions indicated by dotted circles near *a*, *a*.

The screw *v* will give a lateral, and *s* a perpendicular, movement to the tool-carrier.

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301. If it is desired to avoid having a very extended movement of the screw *s*, the arms E, E, may be prolonged beyond *a*, *a*, and two more holes drilled through them. By passing the centres through these latter, the entire frame will be carried farther out.

The screw *v* should run easily, and the spindles, *c c*, *d d*, are somewhat thick in order to avoid bending.

When a greater range of lateral motion for the tool-holder is needed, or if a larger tool-holder (securing more steady work) is employed, the entire frame can be made longer by arranging for one of the arms, E, to pass on to the corresponding centre at its opposite end, beyond the poppet-head.

If working on wood or soft metal, the frame may be left free at B, and the requisite lateral pressure obtained by hand, sliding the frame along the centres *a a*.

302. Circular slide-rest.—The tool-holder can be so arranged that the cutter may be fixed at various angles to the axis of the lathe by mounting it to turn on an axis, with a screw to clamp in any position. A very firm arrangement is shown in fig. 13, plate V.

D is a conical disc fixed by screws: it maintains the ring *b b* in such a manner that it can rotate with friction. This ring carries two projecting blocks *a*, *a*, which correspond with a circular recess *c c* cut in the under-side of the tool-holder P. The entire system *a b* D *b a* and P fit together, and the screw T (shown also dotted at *t*) passes through the two blocks and the tool-holder. When this conical screw is tightened, its upper side engages with *a*, *a*, and its lower side with P, thus firmly fixing the tool and holder, which can, however, be rotated immediately on releasing it.

303. Easy mode of making a slide.—The only difficulty that presents itself in making a slide for the slide-rest, a rule, or any other purpose, consists in obtaining exact parallelism between the edges and an equal inclination of the two sides. This difficulty may easily be got over by proceeding as follows:—

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When the slide is thin, place a plate P, fig. 10, plate XII., on the chuck of a wheel-cutting engine, a straight edge *r* having been previously riveted to P. After roughing out the slide *c c* and making the under side quite flat, hold it firmly against the edge of *r*, and, while sliding it along, a single revolving cutter *f*, or a cylindrical mill-cutter of the greatest diameter accessible cuts the edge of *c c*. Reverse the slide and, after pressing the other edge under the cutter, make the inclination of the two to correspond in the manner explained below. The curvature of the face formed thus will be but slight.

When the slide is of some thickness, the above method becomes impracticable. Mount firmly on the wheel-cutting engine or on a lathe driven by a hand or foot wheel, the plate B, fig. 11, plate XII., with an attached straight edge *r*, supporting it by a pillar *b* passing through the T-rest holder or in any other convenient manner; the direction of *r* must be at right angles to the lathe axis or such that, when a mushroom-headed mill F is chucked in the lathe or on the cutter arbor of the wheel-cutting engine, the slide can be gradually presented to it, as seen at C in fig. 11.

304. *Smoothing the inclined faces.*—To effect this without altering their parallelism or their inclination, take a perfectly true hard flat surface, of marble, metal, or some such substance; glue a sheet of fine emery paper to it, subjecting it to a considerable pressure until the glue is dry. Now prepare a piece of compact wood, as seen at R, fig. 11, plate XII., taking care that it is long enough. File it, dressing the surface *f f* until it makes with the plate the same angle as is contained between the base and side of the slide, *a*. It only remains to hold R steady and to travel the slide backwards and forwards along it, maintaining it in close contact with both the wood and emery surface; and the slide is reversed to do the second edge. In order to be able to manipulate it the more easily with the hand, the slide may have a handle cemented to the face *a*.

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It is needless to observe that before thus finishing off the inclines, the base must be accurately trued.

SIMPLE FORM OF LATHE.

305. This very economical form of lathe can often render valuable service to watchmakers, especially to such as are, unfortunately, only provided with the ordinary finishing turns.

At the end of each centre, a short plate is fixed at right angles, as seen in fig. 5, plate V. The centres are placed in the poppet-heads as shown, and one, *b*, supports the point of the arbor, and the other, *c*, its bearing. The movable poppet-head being thus drawn close up to the one that is fixed, leaves a sufficient length of the bar to hold the T-rest.

The arbor shown in the figure is solid and has a screw *a* to which various brass chucks can be fitted. The face of the chuck must be carefully trued before cementing any object, such as a balance or barrel to it.

DRILLING IN THE LATHE.

Various methods.

306. The perforation of metal when the drill is driven with a bow is often a tedious and difficult operation; in most cases it becomes both rapid and easy when a wheel is used in place of the bow, especially if one of the forms of drill subsequently described (**333—4**) is employed.

The ordinary drill can be used with a wheel in the manner shown in fig. 9, plate IV.

A loose pulley *p* is mounted on the centre in the fixed poppet-head of the turns, and receives in a radial slot the extremity of a pin that is fixed in the ferrule *c* of the drill. The workman holds the object to be drilled, *a*, in his hand against a piece of wood *b*, and, steadying himself against the bar of the lathe, can press it against the drill in the

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required direction; the drill is then set in motion by the wheel.

Fig. 2, plate III., shows another method of drilling. The object, *a*, is made to rotate, and the drill, *f*, held in the centre, *h*, which is free to move in the poppet-head, is pushed forward by the hand with the requisite degree of force.

In fig. 7, plate IV., the drill is held in a special chuck and set in motion. In the opposite poppet-head is a centre that carries an accurately turned disc or table, *t*. The object to be turned is held against the drill and the table is pressed against it: the hand can then maintain both the object and table in position. If desired, the object can be clamped to the table by screws when the drill has centred it, but as a rule the fingers will suffice to maintain its position (**340**). Another arrangement is referred to in article **448**.

A considerable pressure is sometimes required to force the drill to enter the metal: this may be obtained by means of an arrangement such as is shown in fig. 6, plate IV.

A collar *m* with an internal thread is fitted to the loose headstock opposite to the drill: it can be removed at will, but a pin prevents it from rotating. A spindle *f*, diminished throughout a portion of its length and tapped to fit *m*, carries a loose plate *v* at one end and has a handle at the other. It will be obvious that, on turning the handle, the object *e* that has to be perforated will be pressed by the plate against the drill with considerable force.

The handle should be easily removed from the spindle, so that the collar *m* and spindle *f* have only to be drawn from the poppet-head to release the lathe when required for other purposes.

It will be found convenient, when the arrangement shown in fig. 7 is adopted, to set the lathe vertical with the point of the drill turned downwards. There will as a rule be no difficulty experienced in doing this.

Another system of drilling in the lathe and applying

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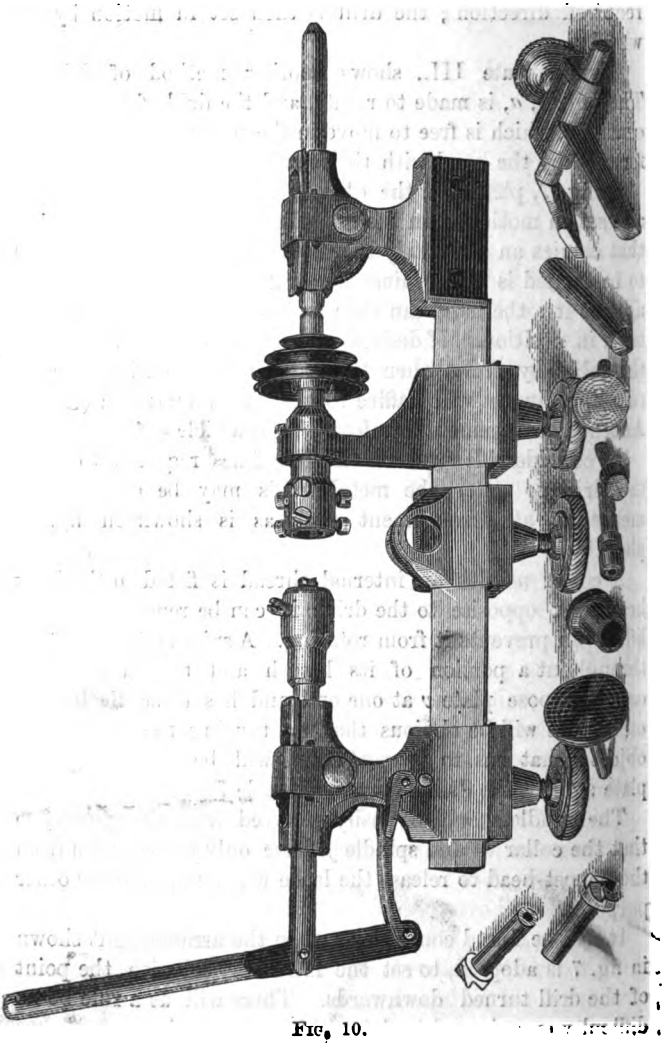

FIG. 10.

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the requisite pressure is shown in figure 10, page 212. The explanation already given in par. **283** renders further details unnecessary. For the mode of using the countersinking rose-cutters, seen apart on the left-hand side, see article **443**.

SUMMARY OF THE ADVANTAGES DERIVED FROM USING A WHEEL IN PLACE OF A BOW.

307. We feel compelled to insist on this point and again refer to it on account of its great importance, because it is mainly by employing tools that are better adapted to the requirements of his daily work that the watchmaker can raise himself from the uniform groove in which so many of his fellow-workers remain. But unquestionably the basis of a systematic assortment of tools and the instrument that is best calculated to make such a collection complete is the lathe driven by a wheel: and this includes both the ordinary turns and the headstock lathe.

The object to be operated upon is more promptly placed in position; the carrier can be more easily attached than the ferrule and nearly always occupies less space. The continuous movement of rotation secures a more rapid removal of metal by the graver and the object is more exactly round: moreover, as the graver is not so frequently displaced, it is less apt to break at the point. In drilling holes, the metal is removed with greater rapidity and the holes are straighter, especially when using the semi-cylindrical drills (**334**). Surfaces are polished more rapidly and better. A single cord takes the place of an array of bows that are constantly in the way. Lastly a lathe with fly-wheel can, if desired, be of very considerable power; admits of using a great variety of chucks for screws, drills, emery wheels, laps, cutters, circular saws, &c.; which, while taking up very little space in the drawers, render an immense variety of services in ordinary work.

Evidence of this fact has already been given in articles **271—5**; to which reference must therefore be made.

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ORDINARY SMALL TOOLS.

308. We shall omit all reference to several tools that are so common as to render any remarks unnecessary, neither shall we again discuss the appliances that are treated of in articles **229—249**.

After discussing a number of small tools, very many of which the young workman had better make for himself with a certain degree of finish, with a view to improve his manual skill and taste, we will proceed to consider the tools of larger volume, such as mandrils, wheel-cutting engines, rounding-up tools, &c.; and we will conclude this portion of the work by explaining the mode in which the accuracy of certain important tools may be tested.

TO SYSTEMATIZE THE DRILLS, TAPS, BROACHES, &c.

309. Screw gauge.—In arranging a set of tools, one of the first conditions for ensuring rapidity and certainty in work is to determine upon a common measure between the broaches, taps and drills; and this can easily be done in the following manner.

Procure a good screw-plate and a draw-plate for reducing round wire to any required diameter.

Draw out a piece of brass or good iron wire to such a thickness that, when slightly tapered at the point to facilitate its insertion into the first hole of the screw-plate a good full thread is obtained without producing too much shaving or straining the metal. The screw is cut off about half an inch beyond the thread, so as to have with it a portion of the metal from which it was produced. The formation of the thread spreads the metal outwards, so that the screw is nearly always thicker than the smooth portion.

The wire is again passed through the draw-plate until of the thickness suited to the second hole on the screw-plate; a screw is formed, as in the first instance, and so on throughout the series.

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310. When this operation is completed, take a thin plate of a circular or rectangular form, and round its circumference cut a number of notches, gradually diminishing in size, that correspond with the cylindrical uncut portions of the screws (J, fig. 4, plate V.).

Mark these recesses with numbers corresponding with those of the screw-plate and, opposite to each, drill a hole of the same diameter as the notch.

The first series will serve to measure, without removal from the lathe if desired, the diameters of spindles on which threads are to be cut; and the round holes are useful for selecting the broaches and drills to prepare holes that are to be tapped.

If the gauge is well made and the drills employed are capable of producing a smooth and clean cut hole, it will be found that the thread can be at once formed without there being any occasion to use a broach. When the correct size is thus determined, the hole can be tapped, using the bow, or by one of the special tools subsequently described (**435—440**).

Series of taps, broaches and drills can be prepared on the basis of this gauge; they should all be marked with corresponding numbers, and the broaches may be fitted with brass rings to indicate the extent to which they are inserted. Such a set, if complete, and maintained in good condition, will be found to immensely facilitate the work of the watchmaker, to effect a great saving of time and to avoid breaking taps and choking up the holes of screw-plates.

Some further details will be given in the articles on drills, taps, and screw-plates.

FERRULES.

311. At the outset we would observe that a ferrule can nearly always be replaced with advantage by a carrier. This can be adapted for use with either a bow or wheel, as it is

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only necessary to make a radial slot in the carrier through which the pin on the loose pulley passes ; or the carrier may itself be provided with a pin that passes into a slot in the loose pulley.

Two forms of screw-ferrule are shown at J and K, fig. 4, plate IV., that are too well known to need description. A convenient modification of J is represented at V, fig. 3, plate V. This differs from the ordinary form in having two separate bars *a b*, *c d*, attached to a solid ring V ; the bars are hinged on screws at *a* and *c*, and clamped together by two screws *b*, *d*. The advantages of such an arrangement are : the ferrule itself is always circular, being formed of a solid piece ; the bars will be rendered parallel by the screws *b* and *d*, and always maintain the ferrule concentric with the axis to which it is fixed.

At L, N, R, P, Q, fig. 5, plate IV., are represented five varieties of ferrule : Q differs but slightly from K, fig. 4 ; R, fig. 5, is not of much value, for, if the object to which it is attached is thick, the screws will not hold firmly, and, if thin, they will project on the other side and catch against the cord of the bow. The edge would require to be thick in order to avoid this inconvenience, and then the ferrule would become heavy and somewhat unmanageable.

The three remaining forms, L, N and P, are often useful in every-day work.

312. A graduated series of ferrules similar to L will be found of great use. They can be at once adapted to a spindle, drill, arbor, &c. They are free from the objection of the ordinary ferrule, which requires the spindle to which they are adapted to be conical and often render it necessary to increase the hole with a broach. The apprentice should make himself such a set ; it will not take much time, and he can easily obtain the requisite screws at the tool-shops very well made.

313. The ferrule P, shown in both front and side elevation, is of the ordinary form, but provided on its face

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with two or three screws with large thin heads, the exact form of which varies according as the ferrule is to be used for balances or wheels. The metal is all removed from the middle, leaving only the rim and projections to take the screws; the ferrule is thus very light. The under sides of the screw-heads should be polished, or, at least, smoothed, and its shoulder should be rounded off in order that they may not mark the crossings of wheels, &c., when used to clamp them against the ferrule.

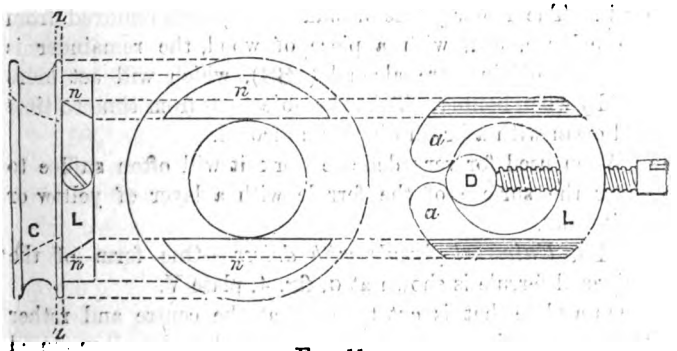

FIG. 11.

314. A very convenient form of ferrule, adapted to receive a spindle of almost any size and to rapidly centre itself, is shown in fig. 11. The body C is provided with two under-cut blocks *n*, *n*, in which a dovetailed slide travels. On clamping a rod D in the manner shown in the figure, the two spring arms, *a*, *a*, open so as to lock the slide in its groove; it is therefore only necessary to place D in the middle of the circular hole in C before finally tightening the screw. It would be preferable that the flange of C be extended as indicated by the dotted lines Z, Z, so as to prevent the gut-band catching against the screw-head.

315. The *wax ferrule* N, fig. 5, plate IV., is one of the most useful. It is deeply under-cut inside, on the side opposite to N, and at N there is a broad ring of metal which

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is heated and covered with a layer of sealing-wax. When required for use the ferrule is held for an instant over the lamp to melt the wax, and the wheel or balance to be operated upon is applied to it. In detaching the object press a knife-edge between the surfaces in contact; but, if the object is fragile or it is desired to avoid all risk of scratching, the ferrule should be held in strong tweezers, which are introduced into the lamp at a short distance above it. On the wax becoming soft the object will detach itself. The looser pieces of wax having been removed from the balance, &c., with a piece of wood, the remainder is dissolved off in pure alcohol (**163**), which will act more rapidly when boiling. Take the object out from time to time and clean with a brush dipped in alcohol.

When used for very delicate work it will often suffice to cover the surface of the ferrule with a layer of yellow or white wax.

316. *Universal ferrule with driver.*—One form of the universal ferrule is shown at G, fig. 4, plate V.

On a plate that is cut through at the centre and rather thin, with a view to lightness, a brass star-piece is mounted on a screw, and this is provided with obtuse-angled or semi-circular notches of graduated size round the edge. Above the star-piece a small die slides between guides, being impelled by a screw. The mode of using the ferrule will be evident from the drawing. When the notch in the star, that corresponds to the diameter of the object to be turned, has been brought opposite to the die and the star is clamped by the screw on which it turns, the object is placed between the two and the die is forced against it by the screw.

A modified form of this is sometimes used in which the star-piece is replaced by a second die, when it somewhat resembles *l d*, fig. 2, plate III.

The holes, 1, 2, 3, 4, in G, fig. 4, plate V., are to receive the driving-pin of a loose pulley when turning with the

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wheel; and the ferrule *c*, attached to the back, is useful when employing the bow.

317. The *loose ferrule, or driving pulley*, is shown at H, fig. 3. The small handle *a* slides on to a pin fixed in the face of the pulley; it is shown in plan at *s*. By inserting the pin *a* in one of the holes, 1, 2, &c., of the universal ferrule, it is evident that the motion may be transmitted to the latter. It will also be seen that, since the pin *a* can occupy any position on the circular arc *r s*, this loose pulley can be used with all sizes of ferrules and carriers that do not exceed it in diameter.

It is to be observed that, when turning near the centre of delicate objects, the driver should be very free.

318. *Spring ferrule.*—When only a slight degree of force is to be applied to an object, this form of ferrule can be used with advantage, as it can be easily adapted to the work and is no thicker than is essential for the proper working of the cord; thus it would be of special service for polishing fine pivots or for finishing or rounding off their ends.

Take a plain ferrule of well-hammered brass, and reduce the thickness of the entire portion G B (fig. 8, plate X.). Then cut it nearly through, that is from *o* to *i*, with a fine saw. This slit is represented enlarged in the figure so as to make the details clear, but it should not be actually wider than that formed by a fine saw.

319. *Improved form of spring ferrule.*—We have introduced the following modifications in order to make it more generally useful. The slit *o i*, which may even be continued still farther down, is made wider, and a screw *e v*, passing through a hole made through the edge of the ferrule, as indicated by the dotted lines *r*, *t*, is used to draw the two halves of the ferrule together and thus to tighten its hold on the work. If it is desired that the central hole admit of a greater degree of variation, the ferrule must be made of steel, thinned down at the points where flexibility is necessary. After cutting the diametral slit, harden and temper. The

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screw may, if preferred, pass in the direction *h h*, the rim of the ferrule being perforated so as to admit a screw-driver in that direction.

320. *Ferrule that moves continuously in one direction with a bow.*—Thiout, in a work published in 1741, describes a fusee that is wound up whether the hand rotate to the right or left. The ferrule here described effects the same result somewhat more simply.

A ferrule, N, fig. 14, plate X. hollowed out on the side towards *c*, is mounted so as to run easily on a perforated spindle *a c b*. It is held in its place by the collar *b* on one side, and on the other by the ratchet-wheel *d* fixed to the spindle *c*. As is seen from the arrangement of the click

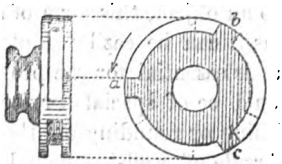

FIG. 12.

work at *y*, when the gut-band descends the spindle will be carried round, but, during its ascent, the click will merely rotate round the ratchet, providing a certain amount of resistance is opposed to the revolution of the spindle.

The ratchet *n* of the ferrule H is also fixed to *a c* and received in a recess in H. The ferrule rotates freely, being held in its place between the ratchet and the collar *s s* which is firmly attached to the spindle. It will thus be seen that the two ratchets, which face each other, will produce a revolution of the spindle in the same direction.

In using this double ferrule, two cords must be attached to one bow, the same distance apart as are H and N. If now an arbor be passed through in the direction *j j* and fixed by the screw at *v*, and if these two cords be passed round the

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ferrules so that one, for example that on N, crosses at the front, and that on H crosses at the back, the axis will be found to revolve in a constant direction whether the bow ascends or descends.

The ratchets are shown between the ferrules, but it would be more convenient to place them against the outer faces; their movement can be made very smooth.

If a circular intermittent motion is desired it may be obtained by fixing at *c* a ratchet with which a click engages whose centre of motion is carried on a detached ferrule, and only this one ferrule would be necessary. Assuming cords to be on both the ferrules, they must cross on the same side.

321. *Balance ferrule.*—Figure 12 represents a convenient form of ferrule, especially adapted for holding ordinary balances. It is made of steel, the face being recessed as indicated by the shady portion of the drawing. *a*, *b*, and *c* are three slots cut in the rim that is left, and they are continued round the periphery in a wedge-shaped undercut to the points indicated by the dotted lines. Having placed the balance on the ferrule with its three arms in the slots, it is twisted in the direction of the arrow until firmly gripped. Care must be taken that the extension of the slots is in such a direction that the pressure of the graver in turning tends to tighten the arms, and they should be near the face of the ferrule so as to allow of a little springing; for compensation balances of course only two notches would be required.

GRAVERS AND OTHER HAND-TURNING TOOLS.

322. For details as to the precautions to be adopted in turning with the ordinary graver, the reader is referred to articles **226—8** in Part III., and as regards the sharpening of gravers, see articles **396—8.**

323. Hooked gravers.—It is needless to do more than mention the gravers that every watchmaker is in the habit of

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making of worn-out files, of various forms to suit his special requirements: but we would remind learners that care is essential in fixing the position of the rest and the inclination that has to be given to the tool so as to obtain a smooth surface, and at the same time a rapid removal of metal.

The most usual forms of the hooked graver are shown in fig. 6, plate X. A will serve to hollow out a plate, barrel, &c.; B for turning the bottom of a barrel without touching the hook; C for forming a barrel-cover groove after it has been roughed out with an ordinary graver. The bottom of a barrel can also be turned with a graver of the form D held on the T-rest at right angles to the bottom, and a slide-rest cutter can be made of this form with advantage.

Some workmen incline the end cutting face of A slightly backwards from the perpendicular to *d d*, fearing lest, in sharpening, it should accidentally be made to incline in the other direction, and so make it difficult to form internal square corners.

324. Gravers for turning square shoulders, &c.—Very few watchmakers are able to finish off a square shoulder by using a graver with the usual point: as a rule, when they are smoothing the surface of the pivot they allow the point to cut a ring in the shoulder, and if, instead of being sharp, the point is dull, a rough groove is the result.

To avoid such a fault it is a common practice to employ gravers with very short faces, but their inconvenience is evident. It is much better to retain the long lozenge-shaped face, but with the point modified, as indicated by B or C, fig. 7, plate X.

The ordinary point, shown at A, can be used for cutting the back slope of a shoulder, B for forming the square-shouldered pivot, and C for bevelled shoulders. The inclination of the face *e d* of B may vary, the angle *e* being more or less acute, according as more or less use is required to be made of the point. This form of graver has the double advantage that a pivot can be turned and smoothed at one

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operation, very little polishing being needed. Moreover, the point is less fragile, and such a graver combines the advantages of those with pointed and square ends.

The length of this small face depends on the work required of it: thus for making a cylinder pivot it may be about a third the length of the pivot; this is found convenient for ensuring that the pivot shall be of uniform diameter. The direction to be given to the face is indicated by the dotted line *e d*, and a lozenge-shaped graver is preferable to one of square section for this purpose. This direction *e d* is very important, and frequent trial should be made so as to ensure its being always produced.

The form C for bevelling off a shoulder does not call for explanation.

Although of less importance than when turning with the slide-rest, the cutting angle of the graver should correspond with the nature of the metal operated on. In reference to this question see article **297.**

325. Spherical turning tool.—A very simple and convenient tool for forming a sphere of metal may be made by taking a hardened steel tube whose internal diameter is less than that of the sphere to be produced. This is ground square and flat at one end, and sharpened by rubbing this flat end on an oilstone. The tool is moved about over the surface of the ball, previously roughed out, and a perfect sphere will soon be obtained, the metal being removed by the internal edge of the tube. If a steel tube is not accessible it will be enough to drill a hole in the end of a softened worn-out file, subsequently hardening it.

DRILLS.

326. The forms ordinarily adopted for the blades of drills are shown at A and C, fig. 2, plate IV. The form C is best suited for perforating brass and other metals having a similar degree of hardness. The blade must not be too

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thick; as, if it were, there would not be a sufficient cutting edge. As the hardness of the metal operated on is greater, the thickness of the blade must proportionately increase, or, what amounts to the same, the two slopes that give the cutting edges must have a less degree of inclination. If this condition of sufficient thickness be satisfied by a drill of the form C, it will perforate steel very well, but its point will rapidly wear. When operating on this metal, therefore, the form A is preferable, especially when the steel is at all hard: such a drill with the corners rounded off and sharpened will last for a long time, if the cutting angles are not too acute. If the metal is not hard, more rapid progress may be made by adopting a blade less flattened than A, that is to say, something intermediate between A and C.

A drill may be asserted to be good if it satisfies the following conditions: the point must be in the middle of the blade; it must be made of good steel that is carefully hardened, without being heated beyond the proper temperature; lastly, it must be quite true—in other words, in rotating it must run with sufficient truth throughout its entire length that it withstands the end pressure required to cause it to bite and does not bend.

327. It must not be forgotten that: (1) if a drill is driven too rapidly it will heat, and thus become softened as though too much tempered; it is with a view to prevent this that, when operating upon iron or steel, many workmen now and then dip the drill into a cold liquid (turpentine is good for this purpose), dry it, and recommence drilling, the hole being liberally supplied with oil; (2) when the blade is left too hard, the cutting edge too acute, or if a feather edge has been left by the oilstone, small hard particles that are detached from the drill will embed themselves in the hole, and this will be especially the case if it is worked too rapidly or with jerks; such particles render the operation of drilling very slow and difficult: (3) and, lastly, for a given throw of the bow, the velocity

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increases as the diameter of ferrule is reduced, and the force applied increases with this diameter and the tension of the string of the bow.

328. To drill steel of a blue temper.—At first not much difficulty will be experienced, but when the drill reaches a certain depth and the metal seems to oppose a gradually increasing resistance, the operation must at once be stopped. If the blade of the drill be now examined with a glass it will be easy to see which points have ceased to cut, producing instead a series of bright rings at the bottom of the hole that are very difficult to remove. Exchange the drill for one of a different form, or, without reducing its width, change the form of the blade; if it was arrow-headed, for example, make it a semi-circle, or semi-oval, or chisel-shaped with sloping edges. All that is essential is that the form be so changed that the bright portions of the surface shall be gradually removed, and that no attempt be made to act on the whole bright surface at once. Until this hard portion is removed, the blade will require frequent sharpening.

Some authorities recommend that the hole be moistened from time to time with dilute nitric acid, which is then washed off, and renewed when a shiny surface is produced. Oil can with advantage be replaced by turpentine as a lubricant for the drill-blade.

The formation of hard shining surfaces is attributed to three causes: (1) to the cutting edge being rounded, rolling as it were and hardening the surface of the metal against which it continues to move; (2) to the drill being made of bad steel or imperfectly hardened, so that small particles break off and are embedded in the metal operated upon; and (3) to a deficiency in the supply of oil, or an excessive velocity of rotation of the drill.

These difficulties may usually be avoided by observing the following precautions:—

329. *Blade of the drill.*—This should be neither as thin

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nor as acute as is used for drilling brass. Its angle should never be less than 100° and the incline should be at about 45°. The forms generally employed are shown in fig. 3, plate XIII., at A, B and C. At first the form A is used, and, as the operation progresses, it is modified with an oilstone slip.

330. *Drilling slowly with considerable pressure.*—If the drill rotates too rapidly or there is not sufficient oil, the surfaces of contact will be heated and shining rings will form. It is well to practise slightly varying the throw of the bow, in accordance with the pressure applied; the stroke should be more decided when the pressure is, for the instant, comparatively great. With continuous rotation, as when a fly-wheel is used, considerable pressure should be applied with moderate velocity. Constantly remove the drill to sharpen, clean the hole and have an abundant supply of oil. Whatever liquid is most effective in maintaining the drill cool will probably be the best; turpentine is better than oil, since it has the additional advantage of increasing the "bite" of the drill.

331. *The part against which the drill acts should be very rigid.*—For example, if a hole is being made for a pivot in a cylinder plug which is not provided with a shellac backing, and is, therefore, flexible, the operation will be more tedious than when the cylinder is filled with shellac.

The firmness is always greater when the object is centred about the point to which the drill is applied.

332. *Making the drill.*—The very best steel should be used, and the precautions indicated in article **87** should be taken in the hardening. If the steel is burnt in this process, no satisfactory results are to be expected of it. To avoid such a danger it is often advisable to leave the blade nearly round and thicker than is required, finishing with a piece of oilstone. Although somewhat more tedious, this method has the advantage of ensuring that, after hardening, all the metal that is most liable to have been burnt is removed.

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The drill must be short, the blade being thick and not much reduced at the shoulder, in order to stand pressure when in use. A drill that has been several times hardened is rarely good.

333. Finished drills.—We would here draw the attention of watchmakers to some beautifully made drills that have recently been introduced and are known in the trade as "finished" drills, in contra-distinction to the well-known pivot drills that are always sold in the rough. They are of two forms, corresponding to A and C, fig. 2, plate IV., for steel and brass respectively; they are made of the best steel, carefully hardened and tempered to the requisite degree; and a principal recommendation consists in the fact that, while being moderate in price, they are of definite graduated sizes, extending from 0·1 mm. to 2·5 mm. (0·004 to 0·1 inch), a range which comprises 37 distinct sizes. Such a set will lend itself admirably to the formation of the gauge described in article **309**; indeed, we believe the manufacturers of these drills supply screw-plates with holes of corresponding sizes.

334. Semi-cylindrical drills.—These drills give excellent results when driven by a wheel, and, although they have been long in use by engineers, they are hardly known to watchmakers.

The simplest form is a cylindrical rod rounded at its end and then filed down to a trifle less than half its thickness, as seen at *b d* and *l i*, fig. 2, plate IV.

The length of the point is greater or less according to the nature of the metal to be operated upon, but under no circumstances must the point itself be sharp. With the form shown at *b d*, some of the rod that is left cylindrical must be partially filed away; a better shape is indicated by the dotted lines, all the metal being removed that is outside the line *i l*. With such a drill the hole is smoothed immediately after it is made by one or the other cutting edge of the portion *i l*. It should be sharpened on the

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round, not on the flat surface (or at any rate very slightly), because the thickness would be rapidly reduced and the blade made smaller. When such a drill does not turn true the back of the blade can be reduced, starting from the cutting edge, it being observed that, with the continuous motion of the wheel, only one edge acts. After a few trials it will be found easy to use this form of drill.

It possesses this very great advantage: when fixed in a drill-chuck, it can be turned exactly round, of the required diameter and finished; so that, whenever replaced in the chuck, one can be certain beforehand that the hole drilled will be of a definite diameter.

335. Fig. 2, plate V., shows, at C and D, another form of semi-cylindrical drill; the first, C, is a front and the second a side view. The angle *a* is formed by a sloping semicircle and the stem of the drill is of less diameter than the head, as indicated by the shoulder *j*. The angle *t s r* and the one between the face D and the plane *b a* must not be too acute.

This drill works evenly, but two conditions must be satisfied; it must be maintained perfectly true by the chuck, and, in commencing, both sides of the blade must engage against the sides of a conical opening that forms the beginning of a hole which has to be enlarged.

336. At F and N M, fig. 2, plate V., are seen front and side views of another form of drill. While acting in a similar manner to the others described above, it differs from them in that the blade also cuts with its two sides; the edges, *p*, *j*, *i*, *o*, are sloped off backwards to form cutting angles. The shape is indicated to the right of M, this portion being the exact inverse of the side N.

As with the drills previously considered, a few trials must be made to decide upon the best slopes for the cutting angles, &c., according to the metal operated upon. They may be retained as left by the lathe, or very slightly inclined, on the faces *p* and *i*. All these forms of drill

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require to be mounted so as to run very true. The point *o* must be accurately central.

A hole that has been already drilled small can be rapidly enlarged by such a drill as this last, the pin *o* having the same diameter as the one originally drilled.

Certain details in regard to the precautions that should be taken in order to ensure that a hole may be drilled straight will be found in article **572—7.**

MISCELLANEOUS SMALL TOOLS.

337. Screw-head sinking tool.—This is usually a cylindrical arbor provided with a ferrule and terminating at the opposite end in a cutting edge resembling a screw-driver with a pin projecting from its centre. A collet slides on the arbor and can be fixed in any position to limit the depth of the hole made by the drill; see *g j*, fig. 1, plate IV.

A series of these should be made of varying diameters; then perforate a brass plate with holes into which the guide-pins of the tools will enter, and cut with them a number of sinks, numbering them to correspond with the ferrules of the sinking tools. The plate can then be used as a gauge for measuring the heads of screws.

It is often advisable to have a second series of cutters provided with cutting edges of the form shown at g^1; they are for use when operating upon steel. The tool *g j* can also be employed for this purpose, but it will be found to wear rapidly.

338. Sinking tool with guide.—This is well known to watchmakers. It comprises a perforated portion E with a foot projecting at right angles. A pointed runner is passed through E and into the hole that requires a sink, thus centring the cannon E, which should be clamped in position by a hand-vice, or the foot of E is at times provided with a clamping screw after the manner of the tool shown at S, fig. 15, plate VIII. (see article **660**). The pointed runner

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is now replaced by a cutting tool which is driven by a bow, the outer end being inserted in one of the holes at the side of the bench vice.

Above the tube E the arbor is fitted with a collet similar to *j* (same figure) by the position of which the depth of the sink is determined.

When this tool is used for forming oil-cups, the end of the drill should have one of the forms referred to in the succeeding paragraph, as is indicated to the right of E, fig. 1, plate IV.; but it is to be remarked that oil-cups are made much better in the lathe.

339. Oil-cup drills or chamfering tools.—The reservoirs that contain a supply of oil at the ends of pivot-holes are made in the mandril with a semi-cylindrical drill or by hand with a chamfering tool of the form shown at B or C, fig. 11, plate IV. A drill gives a clean cut, but necessitates a subsequent polishing of the hole; as to the chamfering tool here referred to, some inconvenience will be experienced in its use, owing to the point being apt to jump out of the hole and make irregular scratches on the brass, which are difficult to remove.

The best shapes of drill for making, or at any rate for reforming or finishing, oilcups are shown at D and F, fig. 11, and in fig. 3, plate IV.

D and F are two drill-blades that terminate in non-cutting circular arcs. The flat curved end is more and more inclined from the top towards the corner, from *i* towards the side *e*; the angle at *i* becoming more acute, and *e* more obtuse towards the corners. The drill will, of course, only cut when rotating in one direction; in the other direction the obtuse angles and the reverse sides of the cutting angles will act as burnishers. Thus if the angles on either side are well formed and the blade has been polished, the surface of the oil-cup will be clean cut and polished.

F, fig. 11, is similar to D, but made from a steel rod. Owing to an error on the part of the engraver, the blade is

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represented too thick, especially towards the summit where its thickness should gradually decrease. Fig. 3 of the same plate will be described in the next paragraph but one.

340. *Observations on making the oil-cups.*—Reservoirs that are made with a bow and drill, or with a chamfering tool by hand, will often be found to be excentric, and, when a pivot-hole is bushed and re-drilled, it proves to be struck from a different centre from the oil-cup. In such cases watchmakers often give themselves endless trouble without securing a cup of good form and well centred. This difficulty can be avoided by using the tool in a lathe driven by a wheel; then, holding the plate in one hand square and centred by means of a runner in the opposite poppet-head, advance this runner with the other hand so as to bring the plate in contact with the drill.

If only a bow lathe is accessible, make a plate runner of the form shown at *t*, fig. 7, plate IV., and hold the plate of the watch or timepiece against it by hand or by dogs arranged for the purpose. The centre can be determined in two ways: either from behind by means of a pump-centre in the body of the runner, or from the front by a pointed centre in the opposite poppet-head. In the latter case the pointed centre would have to be replaced by a drill-holding runner (*h f*, fig. 2, plate III.), and the oil-cup can then be easily corrected or made; the operation is further facilitated by fixing an adjustable collet on *h* to determine the amount of penetration of *f*.

When it is only required to correct the form of an oil-cup, the drill may be replaced by a rod with file cuts on its rounded extremity (H, fig. 11, plate IV.). The reader will find no difficulty in making such a cutter for himself, drawing a file with both hands over the rounded end, but always in the direction of the file-cuts. After covering the surface with lines in this manner, rotate the cutter through a right angle and form a number of cross cuts. Or roughen the surface with a chisel of the form shown at H: after

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making a few cuts parallel to each other, turn the chisel through an angle and repeat the operation. Yet another and more exact method can be adopted which will be given in the description of the making of wheel cutters (**465,** &c.).

341. Chamfering tool.—As is well known, this is used for removing the roughness that a drill leaves at the edge of a hole, or to take off the cutting edge round a screw-head sink, &c., thus forming a bevel-edge. The tool commonly has a flat semicircular blade the diameter of which depends on the size of hole to be made; this semicircle is ground to a cutting edge like a drill, as shown at A, fig. 11, plate IV. Chamfering tools are also made pyramidal with flat faces as at B and C; the angle at the apex is more or less acute according to the depth of chamfer required.

The oil-cup drills D and F are also used for chamfering the edge of a hole.

A cone formed at the extremity of a piece of pinion wire with a cutting edge on each leaf and hardened will be found very useful for this purpose.

342. The two forms of chamfering tool first described leave a series of undulations on the bevel edge, so that, instead of being conical, it presents a number of small facets. This inconvenience can be avoided by using the tool shown at Z, fig. 3, plate IV.

A small disc of hardened steel is pivoted within a recess formed at the end of a rod, the pin on which it rotates being at right angles to the direction of the rod. As is seen in the figure to right of Z, the section of this roller is a rectangle and the surface is carefully polished, the edges being left sharp. It may be worked by hand or with a bow.

Clockmakers make use of a tool for forming oil-cups that only differs from the one above described in two particulars: (1) The disc is fixed on its axis; and (2) the edge, instead of being square to the two faces, is inclined as shown at *j* and at the same time is slightly rounded crosswise.

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A few trials will be found necessary before the most convenient thickness and inclination of edge are arrived at.

343. Hollow chamfering tools.—These, as is well known, are used for removing the angles at the ends of cylindrical rods, of steady-pins, &c., or for rounding them off. Three forms are shown at O, Q, N, fig. 11, plate IV.

O is a round rod the flat end of which has been filed across with the corner of a triangular file. Four cutting edges are thus produced which will act on the end of any object that rotates within them, or *vice versâ*. If it be required to form a very acute angle, two slits must be cut with a screw-head file and the sides afterwards inclined to the required extent with a flat file. This tool will serve a double purpose: (1) to chamfer off the edge of a rod; and, (2) by prolonging this operation to form a point at the end.

As a rule when it is desired to round off, say, a pillar of a clock after reducing its length or from any other cause, a hollow chamfering tool of very open angle is used, a rocking motion being imparted to it round the axis of the spindle: it is better to use a tool of the shape shown at N or Q. The latter, Q, is easily formed by strokes of a rat-tail file at right angles across its end; the other, N, is cut internally with a shaped chisel or with a small rotating cutter to which different inclinations are given during the cutting, as is also done when using the chisel.

344. The tool shown at O, fig. 11, plate IV., has been modified as follows by M. Rozé. The two notches at right angles are replaced by three equidistant notches of equal depth. To make these in a piece of round steel it should be divided on the circumference into six equal parts; then cut the three notches as follows. Calling the points marked on the circumference 1, 2, 3, 4, 5, 6, one notch will lie parallel to the line joining 1, 3 and equidistant between this line and the point 5; a second will be parallel to 3, 5 and midway between that line and point 1, and the third will be parallel to 5, 1 and midway between this and the point 3.

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In a hollow chamfering tool thus constructed it will be found that only the three long sides 1, 3, 5, actually cut and at 2, 4 and 6 are short sides that are set back. But when a file is laid on the face joining two of the former sides, say 1, 3, the short faces 4, 6, will protect the cutting edge 5 from contact with the file.

345. Sinks for bow screw-heads.—In re-forming or making the sink in a bow of a watch-case for the screw-head, the hole will almost always be found to be excentric if an ordinary drill is employed. This inconvenience can be avoided in the following manner.

On a cylindrical rod or arbor, *n a h*, fig. 2, plate XIII., that enters without play the two holes in the bow, fit a small perforated cylinder *c* (shown enlarged at c) that should be lightly held by friction. It must be turned down to the size of a screw-head and filed to a cutting edge at *d*, then hardened and set.

Having mounted a ferrule on the cylinder, slide both it and the bow on to the spindle, which is then placed between the centres of the turns, in the manner indicated in fig. 2. Then press the bow with the left hand against the cutting edge of the cylinder, maintaining it in rotation with a bow, and the sink will be cut. The depth of this sink may be determined upon previously, either by a stop fixed on the rod *n a* at about *s*, or by the position of the ferrule on *c*.

346. The cylindrical cutter of screw-driver form causes much "chattering" when the operation commences; it is better to make at least four cutting edges, filing the portion *d*, while still round, at a certain angle with a rat-tail file to form the edges. Or the face *d* can be cut like a file either by a chisel or by drawing a file over it: the cuts must, however, be in two directions at right angles.

The following is a convenient mode of making the cuts with a file:—

Fix a double guide over a flat file, L, fig. 2, plate XIII., parallel to the cuts, the distance apart of these guides being

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determined by the thickness of the cylinder, C, which is held in a strong screw-ferrule in both hands so as to be moved backwards and forwards between the guides until the cuts are well formed on its extremity: it is convenient to arrange that the ferrule shall then rest on the guides. A ferrule is quite sufficient for this purpose, although still better results are obtained by substituting a cap that ensures, by resting on the guides, that the end of C is perpendicular to its axis.

A simpler method consists in fixing C in the vice and drawing the file with attached guide backwards and forwards over its surface several times. This mode is very good for cutting the rounded end of a steel rod, described in article **340**, for re-forming oil-cups when the chamfering tool has "chattered."

347. Tool for centring rods.—These appliances are well known to watchmakers, who often employ them for marking the position of the hole in brass wire when making bouchons or stoppings (**625.**) It is advisable to have such a tool somewhat large, about a third as large again as that shown at *s r*, fig. 11, plate IV.

The head of the centring punch or drill is filed flat on either side, and this flattened portion passes into a notch in the spring *r* which maintains it in position and prevents rotation when the triangular-pointed blade is pressed against the end of the rod, this rod being caused to rotate in the hollow cone of *s*. Instead of a spring such as *r*, a helical spring is often used; but it then becomes necessary to fix a pin in the drill that slides in a groove in *s*, so as to prevent the drill from rotating.

348. Centring with a set square.—The set square may be used for centring round rods, and the following is a very simple mode of applying it:—

On one arm of the square R, fig. 9, plate V., a triangular plate *c d* is screwed or riveted so that its edge *c d* exactly bisects the right angle, that is, divides it into two equal angles. The flat end of a round rod is held within the

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angle and against the plate, a line being traced on it along *c d*: it is then turned through about a right angle and a second line traced. The intersection of these two lines gives the axis of the rod.

349. Tool for roughing out points.—This is merely the inverted chamfering tool of which two forms are described in paragraphs **343—4**, one of them being also shown at o, fig. 11, plate IV. It will be evident that when the end of a rod is caused to rotate in this hollow cone it will take its form.

In some cases it may be found convenient to replace the runner *h*, fig. 2, plate III., by such a tool, in order to rough out the point on a rod *a*. But it should be remembered that where accuracy is desired, the point will require to be corrected in the lathe.

If the bottom of the cone at the end of o, fig. 11, plate IV., were prolonged by continuing the cuts farther down with a thin flat file, the point of the rod might be formed like a conical-headed screw before it is tapped (see also paragraphs **442—3**).

350. Balance-spring collet tool.—This convenient little tool for rotating the balance-spring collet is commended almost as much by its simplicity and facility of construction as by its usefulness.

A steel rod *n*, fig. 8, plate V., is fixed in a handle T; it terminates in a cone *a* and is drilled with a fine hole as indicated by the dotted lines. A thin wing *b*, pointed at its extremity, is also attached to the handle.

Holding the balance between the fingers of the left hand and the tool in the right, the blade *b* is introduced into the slit in the collet while *a* rests on the balance staff shoulder, the pivot being within the hole in *n*. Now rotate to the right or left until the stud is opposite to the mark on the balance rim, and this may be done without danger providing the tool is held firmly and vertical.

351. Turns for replacing broken pivots.—Fig. 10,

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plate IV., represents a form of this tool which may be made out of one side of an old depthing tool.

The runner *d* has either a hollow or a guard-pivot centre, according as it is desired to support the axis that requires a a new pivot, by its point or shoulder. In the right-hand poppet-head is fixed a small collar, *m*, perforated with a fine hole in its axis which is funnel-shaped at the outer end. The shoulder of the arbor, from which the pivot is broken, rests in this cone, so that this arbor rotates between *m* and *d*. The runner *b* carries a fine drill which must be true to the axis and accurately fit the hole in *m*; by pressing *b* forward with the hand, at the same time rotating the staff with a bow, an axial hole will soon be obtained in the latter.

This tool possesses two advantages: the adjustment of the small collars is easy, and, if the drill is true, its direction may be relied on; it will be less liable to deviate and can support a considerable amount of longitudinal pressure, which is essential when drilling steel that is at all hard.

352. Support for replacing pivots.—This is simply a small bar riveted at right angles to a round steel rod that takes the place of the T-rest in an ordinary pair of turns. The bar is perforated with a series of holes of gradually diminishing diameter, which are funnel-shaped at one end, and thus have the form shown at *m*, fig. 10, plate IV. This cone receives the end of the axis to be pivoted while the other is supported in the runner of the fixed poppet-head. The drill, held in the hand, is introduced at the back of the L-shaped support into the hole that supports the axis, and this is caused to rotate with a bow.

We prefer the arrangement described in pars. **256, 351.** to this system, and would here mention a precaution to which Leroy has directed attention. He noticed that a staff was always more successfully drilled when the play of the drill in the hole of the support was less; it is advisable, then, not to harden this support nor to make it of brass. If desired, a broach can be rotated in each of the holes until

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the drill will pass through with some friction and absolutely no play.

353. Watch-hand holder.—A very convenient form of tool, in which to clamp a hand while enlarging the centre hole is represented in fig. 15, plate VI. Two brass plates, *f* and *g*, are hinged at *m* like a sector (**27**). A collar, *a b*, surrounding the two, is pivoted at *a* and has a clamping-screw *b* by which the two plates can be forced together. Several circular sinks of different sizes and equally divided between the two plates, are cut of a depth varying from one-half to two-thirds that of the plates, and they must be made to increase in diameter as they get deeper, thus resembling the internal groove that receives a barrel cover. The plate *a* is cut away along the portion *c d* and grooves are formed to leave passages open between this surface and the bottom of the sinks in *g* and *f*.

When it is required to enlarge the hole of a watch-hand, place it, inverted, in the hole of suitable size, as shown at *c* of the figure, and tighten the screw *b*. Held round the whole or greater part of its circumference, the hand is thus very firm and its centre hole can be enlarged without risk either with a drill or broach; the hand will not show any marks due to the pressure with which it has been held.

354. Common hand-fitting pliers.—The sliding tongs with large flat head, perforated with a number of holes in which the head of a hand is clamped when the opening requires to be enlarged, are often useful, but we feel them to be less so than the holder just described. It is desirable that the inner faces of their jaws, which are usually left rough, be at least smoothed.

355. Another form of watch-hand holder.—M. Fiquemont has devised the simple little tool shown in fig. 7, plate IX. It consists of a short brass rod R, perforated lengthwise and having a thread cut externally on the surface *a b*. It should be reduced in thickness below this tapped portion The rod, shown also in longitudinal section at P,

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is cut into four quarters by two slits from *a* to *b*, which are at right angles and leave the points as indicated apart at *d*. The elasticity of these four quarters should make them take the form of a reversed cone when holding a hand, so that the ascent of the screw *c* shall tighten them.

Within the head *a* of the tool is formed a circular recess, so that, if the reversed head of a watch-hand be placed within it and the screw made to ascend, it will be held very firmly by the circumference as seen in the figure. The hand will thus be perfectly free to adjust in any way that is needed for fitting it while held at the end of the tool, and without being removed before the work is complete.

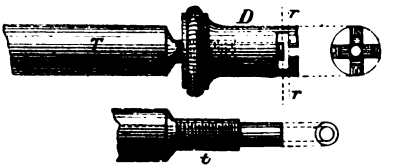

FIG. 13.

Three or four sizes will suffice for all ordinary watch-hands.

A tool may be made in a similar manner, except that the screw is not divided by the longitudinal slits, and the hand is held against the point by a lantern (similar to those of a screw-point tool) which must be cut away in the manner indicated in fig. 15, plate VI., explained above (par. **353**). An assortment of three or four lanterns will render the tool serviceable for all sizes of hand.

356. Clip for holding escape-wheels while cleaning. —A mere inspection of M, fig. 15, plate X., will make the arrangement of this little tool evident. The fork is made of a piece of brass rod and its two arms are elastic, a handle being screwed into the lower extremity.

Two small steel jaws are fixed to the upper ends inclined

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towards each other, and, in using the tool, it is only necessary to press with two fingers on the heads of the screws, when the jaws will open. Having placed the escape-wheel pinion between them, the wheel will be firmly held so that its teeth can be easily cleaned, &c.

357. The appliance shown in fig. 13 can be used for a similar purpose, and is further especially serviceable for holding an escape-wheel that is not riveted to its pinion. It consists of two parts, a handle T, shown separate at *t*, which is drilled throughout its length and tapped externally at the portion *t*, and a collar or nut D, the end of which is traversed by two cuts at right angles that resemble the letter T in section. If the tool is intended for holding escape-wheels that have three instead of four arms, this cross must be replaced by three radiating grooves of similar section. The position occupied by the wheel is indicated by the dotted lines *r r*, and it will be evident that, when the flat end of T is screwed up against this wheel, after dropping it into the cross and slightly turning round the axis as in a bayonet joint, it may be firmly held. The safest mode of introducing the wheel is by holding it on a broach, which is subsequently removed.

358. Tool for testing the truth of a cylinder escape-wheel.—The two following paragraphs will serve to supplement the details already given in the *Treatise* on this subject.

The small tool shown at D, fig. 15, plate X., can be advantageously used in place of the plain arbor commonly employed for testing the equality of the spaces in such a wheel. The plate D, which may be mounted on three feet, is traversed at its centre by the smooth conical portion *f* of the screw *f v*, tapped somewhat tightly into a cock fixed to the under side of the plate. There is a radial slot, *a c*, cut in the plate large enough to allow an escape-wheel pinion to move freely. An inspection of the figure will make evident the manner in which the tool is to be used: a wheel being

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placed as shown, or with the reverse side upwards, is made to slide towards the centre, gradually raising the screw until the largest space is found to admit *f* with contact at both sides. All the smaller spaces are then carefully opened until they admit the cone in the same manner as the largest.

359. *Novel tool for the same purpose.*—When the spaces are adjusted in the manner explained above, or if the length of the teeth is measured in a narrow gauge plate, there will nearly always remain a certain degree of irregularity in the teeth. As we have already said in the *Treatise* (p. 208), a more efficient means would be for the gauge to embrace both a tooth and space, and this condition is satisfied by the following appliance.

The slide *k k*, fig. 12, plate X., is dovetailed into a plate level with its surface, so that *k k* can be moved in a vertical direction by a screw ; it is perforated with a series of holes of gradually decreasing diameter. To the same plate are also fixed: (1) a smooth tongue, *b*, with a foot and screw ; and (2) a second tongue *j*, terminating in an index *x n*, which is movable about a pivot *x* and held against a pin in the plate by a light straight or spiral spring. The extremity *n* traverses a graduated arc.

Having introduced the pinion of the wheel, or the arbor on which it is held, into a hole of the slide that it fits without shake, and brought this hole to the position indicated in the figure, apply a slight pressure to the wheel in the direction of its rotation. With one tooth resting against *b* the tongue *j* will be held by the spring against the next and the reading of the index is to be noted accurately. Withdraw the wheel slightly, and, placing the succeeding tooth against *b*, take a second reading, and so on round the entire circumference.

Of course, the delicacy of the instrument will be increased by lengthening *x n* in comparison with *x j*.

360. Press for removing studs.—Fig. 8, plate IV.,

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represents a small press which we employ for this purpose.

It consists of a thick strip of metal, C, spreading out like the letter T at the end which is not shown, so as to form two feet, the screw *j* being a third so arranged that the T rests horizontally. The disc *d* (shown also in plan) rotates on the screw *j*, and is partially enclosed in a horizontal slot. Round the circumference of *d* are four rectangular notches of different sizes. The holes indicated by black dots on the plan receive the point of the screw *v* which clamps the disc when the notch corresponding in size with the stud to be removed has been brought under the small cone projecting from the spring *b*; the other end of *b* is fixed to the T-shaped piece C. The mode of using this little instrument will at once be evident. Resting the right arm on the bench and, with the left hand, bringing the wing of the cock above the notch in *d*, the other hand presses upon the milled button of *b*, forcing the conical pin against the stud and thus removing it from the cock. The screw *a* can be adjusted so as to prevent too great force being applied.

361. Tweezers for removing studs.—One form is shown in fig. 10, plate V. The upper arm, H, is bent downwards as indicated at *g*. The lower arm is shorter and carries a separate piece *n m* which slides under two screws *s*, and ispressed forward by a spring *r*. The action will be easily understood; the extremity *m* rests against the stud, and *m n* is forced backwards until the point *g* is exactly over the stud pin. A simple pressure of the finger will then suffice to remove the stud.

A still more simple pair of tweezers for this purpose may be made by filing a square notch in the end of one prong of an ordinary pair with broad noses, and setting a pin opposite to its centre in the end of the other prong.

362. Tool for tightening watch-hands.—This differs from fig. 16, plate VI., described in article **365**, in the following particulars:—

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Instead of movable shoulders (*d*), a riveting stake or circular steel plate with holes of varying sizes is fitted to the bed of the tool; each hole must be truly cylindrical and have its upper edge rounded off, being brought under the punch as required in the manner indicated in fig. 17, plate VI., where A A is a vertical section of the bed through the axis of one of the holes.

A small projecting pin is held by friction in the punch *p* as shown by dotted lines in the figure, and its diameter is a trifle less than the hole in the hand is required to be.

Having softened the centre of the hand if necessary, and brought the proper sized hole under the punch, it is oiled inside and the hand placed as shown; a blow is then given with a hammer on the head of the punch.

In order to avoid disfiguring the centre of the hand it is a good precaution to limit the path of *p* by a firm screw-stop that operates when the distance between *p* and A A is equal to the thickness of the hand.

363. Cannon-pinion tightener.—On a small brass block of the form shown in fig. 14, plate V., a rectangular die, terminating in a blunt chisel edge, slides vertically under a plate *r*. A steel bed-plate *s* is firmly riveted to the brass and slightly dished in the portion of its face opposite to the die, so that, when a cannon-pinion is placed on the support and the die gently struck with a hammer, it will be sufficiently contracted to ensure the requisite adherence to the set-hands arbor.

If fears are entertained lest the pinion should be cracked with the blow, it should be placed loosely on an arbor and held in position.

The ordinary forms of tool for this purpose, consisting of two jaws pressed together by a bent spring, are liable to exert too much or too little pressure. If too great the hand cannot estimate the effect of the blow, and if insufficient the upper jaw is liable to move obliquely whenever it is not struck quite straight.

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If a cannon-pinion, while adhering sufficiently, has a tendency to come off the set-hands arbor it may be corrected by the method explained in paragraph **618.**

364. Set-hands arbor tool.—Many jobbers use a hammer or the tool described above for tightening the set-hands arbor in the centre or cannon-pinion. But when this is done the arbor is nearly always bent so that the minute-hand which it carries passes nearer the dial at one place than at another.

We have employed with advantage the device shown at P, fig. 8, plate V., the mode of action of which will be evident at a glance. An arbor that is too loose is introduced into the hole, *c*, and at the top and bottom of the slack portion two punch marks are made opposite to one another. The punch having a conical or three-sided point, will occasion an extension of the metal round each mark; if a smooth file be passed over the surface so as to remove the burr, which would not offer any permanent resistance, sufficient projecting metal will be left to secure a sound and lasting friction when a little oil is applied.

If the arbor is well supported immediately beneath the punch, it will not be distorted by any moderate impact. It is advisable before operating upon the metal to ascertain its degree of hardness.

365. Pinion riveting tool.—The simplest form is that shown in fig. 16, plate VI. The pinions, with its wheel in position, is placed on the hardened steel shoulder, *d*, the end to be riveted being upwards. The riveting is then struck with the polished end of the hollow punch *a*. If it be required to spread the riveting, a punch must first be used that is rounded from within outwards, to be followed with a perfectly flat punch. A little practice will at once enable a workman to select the best form of punch.

The movable shoulders *d* should be very hard and polished, funnel-shaped downwards and carefully fitted to the bed, so as to be firm and central with the punch. If these pre-

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cautions are not taken the pinion will spring and the riveting will be imperfect.

Instead of separate shoulders, *d*, that can be exchanged as required, some watchmakers prefer to adjust an ordinary riveting stake to slide under the punch, and it can be clamped when the proper sized hole has been brought into position. Others employ a thick round steel plate, hardened and slightly tempered, which is pierced with a number of holes of varying size round its circumference, so that all their centres can be brought to coincide in succession with the axis of the punch.

These tools will produce good work if the bed that resists the blow of the hammer is firm. If there is any vibration or elasticity the riveting will be bad.

366. Tool for closing up barrel-holes, screw-holes, &c.—The arrangement above described and shown in fig. 16, plate VI., can be used for this purpose. In repairing watches it is often found that screws hold badly or not at all, and the holes at times cannot be satisfactorily bushed. In such cases it becomes necessary to close them, an operation which any intelligent workman can perform very well in the following manner. Replace the collar *d* by one that is rounded at the top and provided with a pump-centre. This can be merely a pointed steel rod that passes through the collar from below with slight friction, and is forced upwards by a light spring fixed by a screw, so that, on undoing the screw, the rod can be removed. As the collars are all funnel-shaped downwards it will be seen that the same pump-centre may be made to serve for all.

To use the tool, centre the hole to be closed by means of the pump; then bring down the hollow punch, *a*, and strike it as in riveting a pinion. A small circular groove will be formed round the hole which, if the punch is in good order, will be perfectly even.

The form of the punch is very important; the watchmaker must decide for himself by trial as to the most con-

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venient shape. The thickness of the ring of metal may be modified; it is rounded off in a semicircle by some, and curved inwards or outwards by others.

Instead of a pump-centre below we have often used punches that were themselves provided with a pump-centre and helical spring. Either form gives satisfactory results.

The holes of barrels can be closed with a punch that is only depressed at its centre enough to avoid the point of the pump-centre. When the face is more or less rounded the hole will be closed by forming a cup as with a chamfering tool. The hole may then be enlarged if requisite with a round broach or an arbor covered with white wax. It will thus be hardened, and the cup-shaped recess will serve to retain the oil, while the somewhat thinner hole will probably be in a condition to resist friction as long as formerly.

When the hole is of moderate thickness, and it does not require much reduction in diameter, this method will be found satisfactory; barrels thus treated have been found to stand for ten years without appreciable wear. When the metal is thicker, however, the spreading inwards is very slight, and there is some danger, in using a round broach to it, of straining the metal or detaching the central ring of the barrel or its cover.

It should be observed that the methods explained above are absolutely useless for closing pivot-holes, and should only be resorted to for barrels on an emergency; the manner in which a barrel, &c., may be rapidly re-centred and bushed will be subsequently explained (**560—1**).

367. Drifting tool.—This appliance, shown in fig. 3, plate XII., is very useful for making holes of round, oval or square, or, indeed, any required form. It takes the place of a punching machine for light work.

The punch or "drift" is screwed into the stock C C^1. A pin *p* fixed in C C^1 prevents its rotation while allowing an end motion along the slot *m n*. The end C^1 is hollowed out to receive the point of a screw B, and a pin, shown near C^1,

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is received in a groove turned in B, thus enabling it to draw the stock in the direction C C¹. The part H is gripped in the jaws of a vice, and a strong handle E is used to advance the screw B B¹. With a tool about three times the size of the figure there is no difficulty in punching the eyes of main-springs, square holes in stop fingers, &c., and it can be made by an apprentice. Of course its strength depends on the pitch of the screw and the radius of the handle E.

368. For heavier work it will be necessary to resort to the punching machine. There are several constructions in use, but the most usual is essentially the same as that of the tool just described. The screw works vertically in a strong bridge that is fixed to the bed in which the counterpart of the punch is held. Great use is made of this machine in factories at the present day, almost every part of a watch being in the first instance roughly shaped by its means. Indeed, thin metal is often left as it comes from the punch, and very perfect crossings of wheels, &c., are thus produced.

Steel does not cut well in the press unless it is soft and homogeneous, and the final dimensions of the object can be more nearly approached according as these conditions are satisfied. Attempts have been made to cut levers, &c., of the exact dimensions required, but it is better to leave a slight excess of metal to be afterwards removed by a mill-cutter or other means. The crossings of steel lever and cylinder escape-wheels are punched out, but the metal used is of special excellence.

Before introducing a piece of steel into the press it is advisable to remove any scale, &c., by pickling (**81**), or with a file.

369. Draw-plate.—Every watchmaker should possess a plate for drawing round wire so as to be able to obtain it of any required diameter (**309**). They are to be had at all tool-shops.

In bushing holes in a brass plate it not unfrequently happens that the brass used for the bouchon is not of the same

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colour as the plate. To avoid such a difference cut off a piece from a plate of the same colour and round it by hand making one end to taper. Fixing the draw-plate in the vice pass this end through one of its holes, and, gripping it in the hand-vice, pull the brass through the plate. Continue this operation through successive holes until the requisite thickness is attained.

No special precautions are necessary, further than keeping

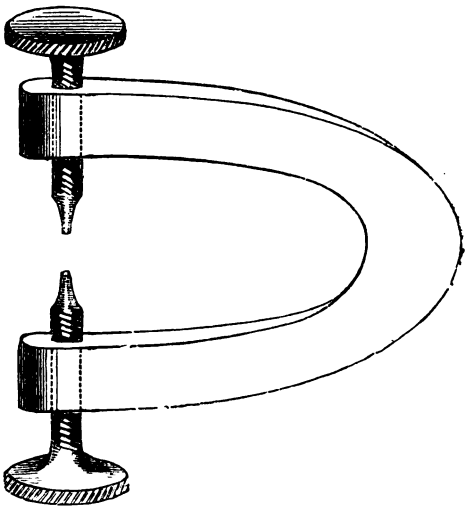

Fig. 14.

the holes well greased and annealing the brass from time to time so as to counteract the hardening caused by the operation (**105**).

Such a plate can also be used for steel wire, and plates with holes of special form, for example those for drawing click and pinion wire, are well known in the trade.

370. Broken screw extractor.—The little tool shown in the accompanying figure 14 is very useful for extracting screws

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that are broken in a watch-plate or in which the slit of the head is much worn. The U-shaped cramp should be rigid and of sufficient length to allow any plate to rotate when the screw is near its edge. The points of the screws must be hardened and two or three may be provided with points of different sizes, as well as one shaped like a screw-driver. The grip on the broken screw will be rendered firmer by adding lock-nuts outside the U-arms.

Another method of extracting broken screws consists in placing the plate, from which all other steel work must of course be removed, in a strong solution of alum, when the steel will be rusted away without damage to the brass. (See also article **427.**)

371. Kay's roller abstractor.—This is shown in fig. 15,

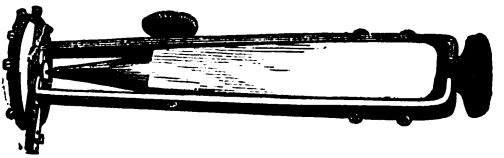

FIG. 15.

and a very few words are needed to explain its mode of action. The nose at the left-hand end of the tool is drilled up so as to receive a balance-pivot without bearing on its point, and can be moved towards or from the two bent prongs by the screw at the right-hand end. A side screw, passing through a slot in the nose, serves to draw the prongs together. In using the abstractor the two feet are brought under a roller and closed by the side screw. If the nose be now advanced against the shoulder of the bottom pivot, the staff can be driven out without damage to either roller or staff.

372. Grammaire, or dividing plate.—One form of this appliance has been described and illustrated in the *Treatise on Modern Horology* (at page 290) : a modification is represented by fig. 12, plate XII. To mark out the crossings

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of a wheel, &c., fix it by the conical-headed screw *t* to the middle of the plate, on which are traced a series of concentric circles (not shown) divided respectively into 6, 8, 10, and 12 equal parts. By laying the little ruler *r r* over the wheel blank and using these division marks as a guide, 3, 4, 5 or 6 radii can be drawn to serve as guides for cutting out the arms.

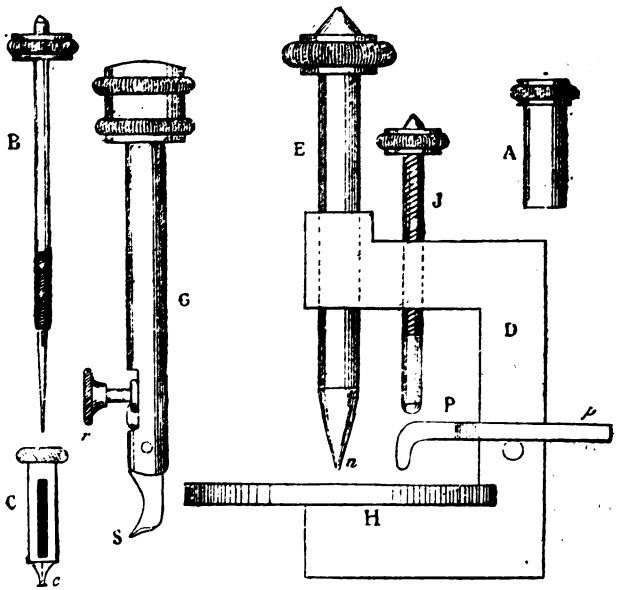

FIG. 16.

If it is desired to indicate the width of the arms instead of a mere central line, a series of holes must be drilled at the division marks and screws with tapered points tapped into them from below. Resting the ruler against these cones, the arms can be drawn of any required width according to the distance to which the screws project. No further explanation is necessary, for the figure shows: (1) a

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grammaire adapted to mark out a four-armed wheel, these arms being indicated by dotted lines ; and (2) the small ruler *r r* cut away at the middle so as to avoid coming into contact with the conical-headed screw.

373. Jewel-resetting tools.—The method adopted in setting a jewel-hole has already been explained in article **211**, and from the account there given it will be evident that the tools employed are of the simplest description.

Jobbers, however, frequently have to re-set a jewel-hole, and have not the skill requisite to enable them to do it in the lathe ; various designs of tools have been introduced, therefore, in order to facilitate the operation. One of these is shown in fig. 16, and a few words will suffice to explain the mode of using it.

D is a solid frame to fix in the vice, and having a table H at right angles to the centring spindle E. P *p* is a dog for maintaining the watch-plate, &c., in position, and it may be clamped by the screw J. After the plate has been centred by E, this spindle is replaced by G, the stem of the thumb-screw, *r*, passing down a slot in the body D. By rotating *r* the point S can be moved radially and the jewel can then be "rubbed-in" by merely rotating G between the fingers. If, however, the old setting is imperfect, E must first be replaced by the socket A ; into this the spindle B is introduced and the lantern C is screwed on to its lower end. This lantern is slit longitudinally, and, after it has been inserted in the hole, B is screwed down until *c* fits this hole, when the spindle is made to rotate. The setting is thus prepared for the jewel, which is then rubbed in by S as already described.

Various modified forms of this tool are to be met with in tool-shops ; one of the best consists of an opening piece closely resembling B C, and the rubbing-in piece is a stock, to which a number of concave-ended smooth steel pieces of various diameters are fitted. Both of these tools are handled in the manner of a watchmaker's screw-driver with loose button. It will be evident, however, that all these appliances are of

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the nature of makeshifts, and as a rule they cannot be relied on for minute accuracy.

374. Swing-tool for facing pinions and ratchets.—This consists of a ring A, fig. 14, plate VI., with two short centres fixed by screws at *d*, *d*, and points let into its outer rim at *n*, *n*.

The axis of the ratchet to be smoothed or polished having been placed between the two centres *d*, *d*, so that it can be rotated with a bow, the tool is supported by the points *n*, *n*, in a pair of turns.

It is then only necessary to apply the polisher P, while the arbor is maintained in rotation by a bow; the arbor is capable of such a variety of movement, that the polisher maintains itself flat without difficulty, and a very true smoothed face is the result.

375. By slightly modifying the form of this tool it can be employed for facing pinions. These changes are indicated at S, fig. 14, plate VI.

The ring A is replaced by a thick plate perforated with a hole in its centre, in which short polishing cylinders or discs are placed, being fixed by the screws *a*, *a*. These cylinders or discs are perforated with a hole, which is funnel-shaped downwards and receives the axis of the pinion to be faced. The principal plate is mounted on pivots or on two screws *r*, *r*, so that it can move freely in a fork which is fixed in a handle, S; the two branches of the fork thus take the place of the poppet-heads in the tool described above. Holding this handle in his hand, the workman brings the central polisher in contact with the face of the pinion, which is rotated with a bow. The polishing is easily accomplished, since the disc maintains itself flat against the end of the pinion.

The same tool can be used for polishing various flat pieces, an end-stone cap, for example, which may be set in wax on the central disc. It is then brought against a rotating lap, holding the handle very short; or, fixing the handle in the

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vice, a glass or metal polisher may be applied to the surface. The movement of which the disc is capable will ensure flatness being maintained.

376. *Another tool for facing ratchets and pinions.*—An old depthing tool is very easily converted into one fo smoothing, polishing and snailing surfaces. It is only necessary to support the pinion or ratchet between one pair of centres as indicated in fig. 18, plate VI., and between the other pair an arbor that carries a small lap (of steel for smoothing and copper for polishing), with the edge bevelled off as shown by dotted lines. The flat face is charged with a suitable material and brought in contact with the pinion, and they are set in motion by separate bows on their respective ferrules. (See also article **178.**)

377. Tool for polishing staves, thick pivots, &c.—This is the same depthing tool modified in two particulars (fig. 18, plate VI.).

(1.) The lap is not bevelled at the edge; it is, on the contrary, thick and exactly square with the face.

(2.) The two runners that carry the lap are united by being clamped to a metallic arc *b d*, and are free to slide lengthwise in their poppet-heads; they can thus be moved as a whole towards the right by hand, while a spiral spring *h* tends to force them towards the left. This backward and forward movement carries the lap along the revolving axis from the extreme end of the pivot to its shoulder.

Barrel arbors, centre-wheel pivots, &c., can be conveniently polished on such a tool. The two bows should be so arranged that the arbors rotate in opposite directions.

If a new depth tool is employed for polishing its accuracy will obviously be destroyed, but one that has already become unserviceable is excellent for the purpose. In its absence various appliances can be obtained at the tool-shops that can be adapted.

378. Tool for flat polishing.—The following is unquestionably the most simple :—

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A thick brass plate is provided with three strong screws arranged in triangular form (G, fig. 17, plate VI.) and far enough apart to ensure that, if the plate is reversed and rests on their heads, it will remain flat when moved by hand over a polishing surface.

The screws should fit tightly or be provided with lock-nuts.

We believe that every watchmaker must be acquainted with this little tool. The object to be smoothed or polished is fixed with shellac or sealing-wax to the middle of the triangle formed by the screws; the level is then adjusted so that, when resting on a flat surface, the object to be polished coincides exactly with it. The polisher (for example, a sheet of ground glass) is charged with oil-stone dust or polishing rouge, and the object is passed over it until perfectly flat and smooth.

379. For smoothing, it is best to use a large sheet of iron or steel. For polishing, copper or bronze is preferred. Ground glass may be employed for both operations; it must be hard and perfectly flat.

A disc rotating in the lathe or mandril, &c., is often used.

The tool may be inverted and rest firmly on a cork, the polisher being then moved backwards and forwards by hand, and always in contact with the three screws.

It is best to use soft dead wood for cleaning the polished surface; in its absence use soap, then wash and dry with a soft linen rag. The object is detached by heating the tool, and is cleaned by boiling in spirits of wine; afterwards pass through pure spirits of wine at the ordinary temperature and dry.

380. This tool can be employed for polishing small surfaces, such as the end of a rod, of a barrel arbor or a screw-head, as well as for those of greater extent. But it appears needless to enter into further detail.

Instead of three screws some workmen only use two, at

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some distance apart. The object to be polished, being placed at the third corner of the triangle, takes the place of the remaining screw.

Lastly, if a band be fitted to one side of the brass plate, as shown at *b*, fig. 17, plate VI., and held by two screws, it will often be of service as a clamp for fixing the object, as at *s*.

381. Flat pieces can be polished on a revolving lap worked by the foot, being simply held in the hand or in a piece of soft leather; but a certain amount of practice is needed in order to do this successfully.

The small swing-tool described in par. **375**, and shown at s, fig. 14, plate VI., can also be used for maintaining the necessary flatness.

UNIVERSAL MANDRIL.

382. The watchmaker who is provided with a well-made lathe of sufficient dimensions can often dispense with a mandril: it is, however, a most useful tool, especially to those who cannot well afford either the outlay or the space that is required for a large collection of special appliances. Its management is not difficult, and, although the plate is somewhat heavy, a moderate amount of practice will enable a workman to do very delicate work by its means.

Although this tool is now well known, comparatively few watchmakers are acquainted with the number of uses to which it may be applied; indeed, it often happens that after making two or three fruitless and ill-directed efforts to work it, this valuable tool is left, useless and spotless, as an ornament in the shop window.

383. There are two forms of mandril ordinarily met with in this country; they are respectively of English and Geneva construction. The latter, having several attachments in addition to those present in the English form of tool, will alone be described. It is shown in fig. 2, plate

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VI. The principal feature of the lathe is the hollow arbor H that carries a plate *p*; motion is communicated to them by a wheel and pinion that are rotated by means of the handle *m*. (In many forms of mandril, however, the wheel and pinion are replaced by a cord and pulleys. With a view to avoid the driving-pulley projecting too far forward, as well as to take the strain of the cord off the bearing of the arbor, the arrangement shown in fig. 3, plate III., is adopted; *s* is the pulley on the arbor, *t* an idle pulley which can be moved along a vertical slot to tighten the cord, and *n* a third to which motion is given with a handle by hand.) Within the arbor is a carefully fitted pump-centre pushed forward by a spiral spring. A small pin is fixed in the body of the pump and terminates in a button *b*, by which the entire pump-centre can be drawn within the arbor, where it is maintained by *b* resting in a bayonet-joint; or, in some instruments, it is fixed by tightening a screw at *b*.

384. The face-plate *p* carries three pairs of dogs, as shown at *g*, *g*. The object to be turned is held between their jaws by screws *l*, *l*, after having been centred with the pump-centre.

Two forms of dog are used: the double dog, such as is indicated at *g*, *g*, which maintain the object at some distance from and parallel to the face-plate; and the simple dog, one form of which, with the clamping screws removed, is shown at S, fig. 1; these fix the object against the face of the plate itself.

On the bed A of the mandril, the slide B travels; it can be clamped in any position by a screw, and carries the two slides at right angles that constitute the main portion of the slide-rest. The movement backwards and forwards is obtained by means of the screw D, and motion in a plane at right angles to the bed by a handle which is partially seen at *c*.

At *f* is a split nut that can be fixed in any position by

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screws: this nut is useful for limiting the movement of the graver in a direction parallel to the face-plate. With a little experience it is often easy to do without such a stop for ordinary work.

385. But, on the other hand, in many cases it is absolutely essential that a series of cuts be of exactly the same depth, as, for example, in making the cutters described in article **468**; and, in the elaborate machine-tools used at the present day for the manufacture of watches, the stop is of primary importance. There are many systems in use: the one represented in fig. 6, plate XII., is adjustable and gives good results.

The slide is advanced by two screws of the same pitch, C D, *c d*, the latter working within the former. To move the tool-holder turn the handle A, and when its small stud comes in contact with the disc *b* it will cause *c d* to rotate. When the cutter has been advanced to the required depth, tighten the screw *n*, and, as *e e* is divided by a saw-cut, the screw C D will by this means be locked. To withdraw the cutter the handle A is now turned in the opposite direction, *b* will be released, and only the screw *c d* will act, and any subsequent forward motion of A will be arrested when the stud is again in contact with the disc *b*.

386. At E, fig. 1, plate VI., is shown the poppet-head for centring from without and for drilling, and fig. 3 shows two runners for this poppet-head. *a* is for centring or "uprighting," and *p* for drilling. The depth to which the drill is introduced with this latter runner can be regulated by means of the stop-nut *e*.

The T-rest for hand-turning is shown at T, fig. 1.

It seems useless to further extend our description of the tool; if placed before the eyes of the reader and manipulated for a few minutes by an experienced watchmaker or dealer, he will be more likely to understand its varied applications than by reading many pages of explanation that must be more or less obscure.

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387. Two conditions must be satisfied in order to work the mandril with facility :—

(1.) The cutters must always be set to the proper angle (**297**), and

(2.) The workman must have acquired by practice the knack of using the two hands independently. In other words, it is essential that, while one hand drives the face-plate at a uniform speed by the handle *m*, the other hand continues to be entirely independent of it and to advance the graver with whatever speed is best suited to the metal operated upon, without allowing this rate of motion to be in any way influenced by the velocity of the other hand.

In a word, the workman must have a perfect mastery of his two hands, and they must move quite independent of each other; otherwise the cutter will advance by starts, will often break, and will spoil the work. Practice on sheets of brass will soon enable him to adjust the rate of advance of the tool so that it gives the best attainable cut.

388. Wax-plates and collars.—A sink is cut on the mandril by fixing the object between the dogs when of a form that admits of doing so: as, for example, the plate held in *g*, *g*, fig. 2, plate VI. But as a general rule the object would either hold badly or would be damaged by the dogs; it must then be set in shellac or sealing-wax on a plate that is perforated so that the point of the pump-centre may be brought into contact with the object; the plate only is then clamped in the dogs.

When re-forming the sinks—for example, in a watch-plate or barrel cover—the cementing can be dispensed with if an assortment of rings is provided, the two faces of which are perfectly parallel; an internal groove should be turned on either face, in the manner indicated at R, fig. 1, plate VI. When the dogs are single, these rings will rest against the face-plate, the dogs pressing upon the watch-plate itself or similar object placed in the groove of the ring. With

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double dogs the ring will, of course, rest on their supports while the dogs themselves bear on the plate.

If only one face of each ring is utilized, it may be provided with screws for fixing a plate, barrel, &c., in position.

389. To centre from within.—When the object is of such a nature or so thick that its central hole cannot be damaged by the pump-centre, this hole is simply placed on the point of the pump which is then pressed backwards and the object clamped in the dogs, taking care not to disarrange anything. It is then centred and the pump may be drawn back.

A delicate object can be centred in a similar manner if the pump-centre is advanced very gently to the level of the dogs while the object is resting against their inner jaws, care being taken to hold back the pump so that it merely touches the central hole: the pump is then drawn in and the dogs gently clamped. Although this method is perfectly safe with an experienced hand, it is dangerous, especially when centring from a jewel-hole, for a watchmaker of only moderate skill; the dogs are, moreover, apt to be displaced, so that the operation may have to be several times repeated. Better methods will be given subsequently (**404-411**).

390. To centre from the front with runner.—Having placed the poppet-head E, fig. 1, plate VI., on the lathe-bed, it is a common practice to centre by means of the runner *a*, fig. 3.

This method is unsatisfactory. The object is nearly always excentric, and the edge of the central hole is often damaged by the pressure that has been applied to it.

It would be well if this mode were given up and the runner *a* were only used for uprighting and drilling.

Good methods of centring from the front will be found in paragraphs **405—8.**

391. Uprighting and drilling.—The hole in a cock to correspond to an opposite hole in the plate (which latter

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must be centred by the pump) is marked by means of the runner *a*, fig. 3, plate VI., used precisely as in an ordinary uprighting tool (**503**). The hole is then drilled, or a hole already there is enlarged in order to make it concentric, by substituting the runner *p* for *a*, a drill being fitted to its extremity.

This runner must be exactly in the axis of the pump, and the drill must also be carefully centred, conditions that can easily be satisfied if the directions given at paragraph **413** with regard to drill-holders are observed.

When the blade of a drill is not rigorously central, a circumstance of no uncommon occurrence, it is advisable not to use the runner *p* except for enlarging or trueing a hole already made; as, for example, for bushing a barrel-hole or a centre-wheel-bar hole, &c.

The drilling of a fine pivot-hole by means of the runner *p* presents considerable difficulty in consequence of the weight and friction of this runner, to say nothing of the probability that the drill will not be perfectly centred; it is better, after marking the hole, to drill it with an ordinary pivot drill with its end resting in the hollow extremity *v* of the runner *a*, fig. 3, proceeding exactly as when the ordinary drilling tool is used (see also articles **412, 501—3**).

392. Split ring for uprighting.—This is nothing more than a large collet, turned very true on its two faces and divided into three segments by a fine saw, as shown at B, fig. 10, plate VIII. It may be made about an inch in diameter and somewhat less than half an inch thick, and is found especially serviceable when planting a hole in complicated movements, such as repeaters, where it is rarely possible to use a ring that is all in one piece.

393. Forms of slide-rest cutters.—The usual forms of cutter for use in the slide-rest of a mandril are shown in figs. 5 and 6 of plate VI. A and A^1 are respectively the plan and side view of the most common form. Two inclined planes *i n* and *d c* are formed on the left-hand and under

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sides. The point in which they terminate is cut off square, a cutting edge, which is more or less acute according to the metal to be operated upon (**297**), being obtained by a third incline *c n*. The width of the square cutting edge, indicated at *n* in figure A, varies according to the metal to be operated upon as well as this incline *c n*. It is advisable to be provided with at least half-a-dozen cutters of this form, with edges of varying width and inclination, and even this number is often found insufficient; cutters for steel should never be used in turning brass.

A cutter may be sharpened in the usual manner for ordinary work; but if it is desired to produce very smooth sinks, &c., one that has been carefully polished must be used for the final cut.

The blade should cut with both its edges; the straight edge will serve to form right-angled corners of sinks, while the other edge will form bevels. It is hardly necessary to add that, when a square corner formed by the first of these edges requires to be bevelled by the second, the lathe must rotate in the opposite direction and the cutter be passed over to the opposite side of the centre.

394. C, in the same figure, is a rounded cutter for making circular grooves. F, fig. 6, is for cutting the groove that receives a barrel-cover.

J and V are for forming the "tallow-drop" shoulders of pivot-holes, &c.

It will doubtless be observed that these cutters would form nipples that are dome-shaped and relatively somewhat high, and, for small pivot-holes, the blade would require to be narrower and of a shape that corresponds with the nipple it is desired to produce.

L is for rounding off angles.

S is a convenient shape for smoothing the bottom of a barrel without damage to the hook.

T has a square point; it is used narrow for cutting, for example, the passage under the escape-wheel cock in a

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cylinder watch (see article **417**), and, when made wider, will serve to cut the settings for jewels. In the latter case it may either be square at the end or a little rounded at the corners.

In addition to the use indicated above, v can be employed for raising the edge of a jewel-setting. The method to be adopted in setting a jewel has already been explained (**211**).

With regard to this last form of cutter it may be observed that the ordinary lathe is preferable to the mandril for jewelling, &c.; but, if a watchmaker only possesses the latter, he may learn to employ it for the purpose, and with care he will be able to do this.

395. Slide-rest cutter stock.—It is not necessary that every cutter be made of the full size required to fix in the tool-holder. A very useful little stock may be made after the model of E, fig. 9, plate VI., that takes a piece of thin tool steel of any convenient size, and any number of small cutters of the above forms or others that the requirements of daily work may suggest, may be fitted to it.

396. Sharpening slide-rest tools.—A flat surface turned in the mandril will never be even unless the cutting face *n* in A, fig. 5, plate VI., is smooth, and indeed polished, and its edge parallel to the face-plate. Some care is therefore necessary in sharpening this face.

The requisite parallelism can be secured with certainty by either of the following methods.

397. *First method.*—Sharpen the tool while it is held in the tool represented in fig. 13, plate VI.

On a thick brass plate *l* and parallel to its plane at one extremity *b*, a plate *p* is pivoted. The inclination of *p* to *l* can be varied and it is fixed in any required position by the curved arc passing under the clamping screw *j*.

A small bar *c* is fixed to *l* with its edge set accurately at right angles to the line at b^1 in which the two planes intersect. An examination of the figure will suffice to indicate the manner in which such a tool is used. Having set *p* so that

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it makes with *l* the angle to be given to the cutting face (**297**), the cutter *b* is held against the bar *c*, where it may be fixed with a screw *v*, or in any convenient manner, taking care to leave the portion of the cutter that is to be removed projecting beyond the face of *p* as shown at b^1.

Now pass a piece of smooth oilstone or a disc of steel charged with oilstone dust over the face of *p* until the projecting portion is removed; if a polished face is required, this must be succeeded by a bronze or ground-glass disc charged with rouge.

If the plate *p* is of sufficient dimensions, it will not be distorted, even although only made of hammered brass; but it would of course be better made of steel, hardened if possible.

Some watchmakers adopt another arrangement: they fix a second bar parallel to *c* so that the cutter will just slide between them when pushed by the finger, without play. While moving the stone or disc with one hand the cutter is gently pushed out with the other, pressing it all the time firmly against the plate *c*.

This, however, is merely a matter of habit.

398. *Second method.*—This is indicated in fig. 2, plate VI. Fix in the right-hand side of that portion of the slide-rest which travels at right angles to the bed of the mandril two hardened (and slightly tempered) steel pins. They should be as far apart as possible but at the same height from the bed, and the extremities must be accurately equi-distant from the face-plate *p*. One of these pins is seen at *x*; the other, being directly behind it, is of course hidden.

Now take a sheet of glass that is perfectly flat and not too thin, and having charged it with oilstone-dust or rouge, place it as indicated by the dotted lines *x z*, the polishing face being towards *s*, and work it backwards and forwards while resting against the two pins and the cutter at *z*. Being inclined to the vertical this glass will form a sloping cutting face, and the

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amount of this inclination can be varied at will by moving the screw D.

Instead of pins, two blocks can be fixed to the slide-rest as a means of reducing the wear ; but if the plate is dry where it comes in contact with the pins and these are sufficiently hard and broad, there is no occasion to adopt such a precaution.

IMPROVEMENTS THAT MAY BE EFFECTED IN THE MANDRIL TOOL.

399. The mandril shown in fig. 2, plate VI., together with the ordinary accessories shown in figs. 1 and 3, are such as may be commonly met with in commerce, but the watchmaker should form the cutters, as well as sharpen and polish them himself. The lathe should always be provided with the T-rest (T, fig. 1) ; but the loose poppet-head E is not so necessary. As will be presently seen, it can be very easily dispensed with. The methods described for upright ing and drilling with the aid of properly formed stocks (**413**) are also applicable when the mandril is provided with a loose poppet-head.

400. Two improvements may be effected in the mandril by every watchmaker.

The *first* consists in marking and drilling two or three circles of holes round the contour of the face-plate ; as a rule it is sufficiently thick to take three. If numbers be selected that possess several divisors, the mandril becomes a small wheel-cutting engine that will be found of frequent use. It will be found easy to mark off and drill the circles of holes on a wheel-cutting engine that is provided with a drill-carrier, an accessory which any watchmaker can make for himself. The same may be said of the index, which should be like those of wheel-cutting engines, and should ensure the perfect steadiness of the face-plate. If the three numbers, 56, 60 and 80, be taken, it will be evident that

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they enable us to divide a circle into the following numbers of equal parts :—

56 also gives 2, 4, 7, 8, 14, 28.
60 „ „ 2, 3, 4, 5, 6, 10, 12, 15, 20, 30.
80 „ „ 8, 10, 16, 20, 40.

And, when it is observed that methods are given farther on for subdividing a circle into a number of parts greater or less by one than a number found on the plate (**456**) it will be seen that, from the three circles, 56, 60, 80, we can obtain the following subdivisions : 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 19, 20, 21, 27, 28, 29, 30, 31, 39, 40, 41, 55, 56, 57, 59, 60, 61, 79, 80, 81. If space is available for a fourth series of holes, 72 would be a convenient number to select, as it would give us the following numbers which are wanting in the above list : 18, 23, 24, 25, 35, 36, 37, 71, 72, 73. But the watchmaker will probably be obliged to select numbers in accordance with his special requirements.

Circles of holes are to be preferred to notches cut on the circumference of the face-plate, for, in addition to the fact that, in the latter case, only one subdivision is possible, a blow or violent friction is apt to damage the teeth.

401. The *second* improvement that may be introduced consists in ascertaining what motion of the screws, that advance the tool on the slide-rest, corresponds to a unit of measurement, whether that unit be a millimetre, line or a definite fraction of an inch ; it is preferable, if possible, to select screws that have a pitch equal to this unit of measurement. The scale on the circumference of the button D passing in front of the index *d* (fig. 2, plate VI.) would then enable us at once to read off the depth of the cutter in units and fractions of the unit ; but it is important to note that this can only be accepted as true if the screw is well made and the button is always rotated in the same direction, so as to eliminate the backlash of the screw.

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A similar arrangement applied to the screw that is worked by the handle *c* would enable the workman to ascertain at once the diameters of sinks, and would render it possible to divide a straight line into equal parts in a manner already described (**47**).

ACCESSORIES.

AND MISCELLANEOUS OPERATIONS TO BE PERFORMED IN THE MANDRIL.

420. With a view to simplify the work, we will here give, in a collected form, a number of operations that may be performed in the mandril, among which the practical watchmaker will easily be able to distinguish those that can be done in the ordinary lathe; we will also describe numerous accessories that the workman should make for himself, if he is desirous of making his mandril still more generally useful.

CHUCKS.

403. Prepare a number of chucks of the form shown in fig. 4, plate VI. Some of these carry a small bar with screws by which an object may be clamped firmly to the chuck, an arrangement which is also shown at A, fig. 10, plate VIII.; others have a hole drilled through their axis; others again have a projecting arbor, &c. They may also be made with a flat face on which to cement objects in the ordinary manner.

As it is often necessary to have a considerable surface to cement, for example, a watch-plate, one or more may be made of the form shown at T, fig. 1, plate VII. The lower plate being clamped in the dogs, the disc *e* will be free. If this disc be of bronze or steel it may be used as a lap; if of brass, it may be turned true and used as a wax-chuck, &c.

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The chucks should, as far as possible, be well made, so that they can be truly centred by means of the pump-centre.

One or two may be made of the form *x d b f g*, fig. 1, plate V., having a strong wood screw at the centre that will serve to carry a piece of hard wood, a use of which will be referred to when we consider the making of clock spring-boxes (**568**).

TO CENTRE AN OBJECT.

404. When there is a hole at the centre on the side towards the face-plate, as is usually the case, it is only necessary to place this hole over the point of the pump, pressing it inwards, and then to clamp the object in the dogs, as already explained (**389**); the pump is then drawn within the body of the arbor. Very often, however, there is no central hole, or there is only a mark on the face that is towards the cutter; in such a case it becomes necessary to centre from the front or by the circumference.

405. To centre from the front.—If the object is held by wax on a plate, it may be centred as in the ordinary lathe while the plate is hot, by resting a piece of pegwood on the T-rest with a point placed in the central hole, and observing whether its free end remains stationary.

After the plate has cooled, the accuracy of the centring should be tested by means of a long piece of pegwood which rests on the T-rest brought close up to the object. The pegwood is held parallel to the lathe-bed, and, if the centring is satisfactory, its outer end will not move. The detection of any slight movement is greatly facilitated by placing some fixed object close to the free end of the pegwood. If a motion is still observed the centring is imperfect, and must be corrected in the manner explained below (**407**).

406. *Perrelet's method of centring.*—In principle, this is identical with the one just described; but the pegwood

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index is replaced by the small apparatus shown in fig. 7, plate VI.

A hollow cylinder, of which *a c c* a^1 is a section, is firmly held by friction by its portion *a b* b^1 a^1 in the loose poppet-head (at *v* in E, fig. 1, plate VI.). In the front of this cylinder is fixed a steel ring that is thick at the circumference and tapers inwards, so that the central hole has a cutting edge. The two black triangles represent a section of this ring. The rod *r n* passes without play through this hole and carries a projecting ring at *s* to determine the distance to which it enters the collar *c c*; there is also a small key that corresponds with a nick in *c c*, and thus prevents rotation.

An inspection of the figure will show that, when *s* rests against *c c*, if the finger be placed on *r* and communicate motion to it, the rod *n r* will be able to oscillate in any direction, and to an extent limited by the diameter of the hole in the cylinder. (Owing to an error on the part of the engraver this hole is represented too small; it would not allow sufficient freedom of motion to the index.)

The error in the centring of *r* will be multiplied at *n* in the proportion of *n s* to *s r*: thus if *n s* is ten times *s r*, the motion at *n* will be ten times as great as the actual error at *r*.

407. The instrument is used as follows:—The object to be centred being placed between the jaws *g, g* (fig. 2), replace the slide-rest B by E (fig. 1), having the centring spindle in position at *v*. Slide E towards the face-plate until the point *r* of the rod enters the hole or central mark of the object, and, setting the T-rest close to the point *n*, rotate the face-plate. If the centring is exact, the point *n* will remain stationary. If *n* moves to and fro, give a gentle blow against the edge of the object, which should not be held firmly in the dogs; the blow must be on the side opposite to that at which *n* shows the greatest deviation from the point of reference. Repeat the process until the

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centring is perfect or sufficiently accurate ; then clamp the dogs firmly, taking care not to disturb anything.

In centring from a jewel-hole, an aluminium rod *n s* may be employed on account of its lightness, and it may be terminated in an ivory cone at *r*.

408. There is one precaution to be observed, as it facilitates the use of this appliance; it is advisable that the portion *a b* b^1 a^1 of the cylinder be somewhat long and well made, in order that, while being in the first instance inserted in *v* up to the shoulder, the cylinder may be partially withdrawn and still held firmly. The reason for this is as follows: when the poppet-head is pushed along the bar, a considerable amount of friction resists its motion, and, as the hand cannot always control this motion, it may happen that *r* comes up against the object with some force. To avoid this, bring the point near the hole and then rotate the collar in the poppet-head so as to gently withdraw it to the requisite amount.

The cylinder may, if desired, be fixed by a small screw after the point *r* has been set in position. Or the cylinder might be adapted so as to be attached to a runner in a manner analogous to the drill stock described in articles **413-4**.

409. To centre from the circumference.—Two cases may occur : either the entire rim of the object is exposed, as when the teeth are to be cut in a wheel blank ; or the rim can only be used as a means of determining the centre, as when a barrel has been bushed with an undrilled bouchon. One of the following methods may be adopted, according as is most convenient :—

410. *First method.*—The small tool shown in fig. 2, plate VII., at *d b* S is required. It consists of a long light index *d b* supported on pivots, so that one end *d* travels in front of a graduated arc when the other end is depressed. The foot S is inserted in the support of the T-rest of an ordinary lathe or mandril, so that the short arm *b* rests against the

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under side of the object—for example, a spindle *t*—that it is desired to centre.

Or, having cemented a wheel blank on a chuck of the form shown in fig. 4, plate VI., or clamped it with a screw, the pump-centre being drawn within the arbor, the short arm *b* is allowed to rest against the rim of the blank ; the stem S is received in a socket C to which a rod A is attached (fig. 2, plate VII.), and this rod takes the place of the cutter in the slide-rest. When the face-plate is caused to rotate, any movement of the point *d* will indicate that the object is excentric, an error which must be corrected by gently striking one side of the chuck as explained in the preceding paragraph.

411. *Second method.*—When it is required to drill or merely to centre the hole in a wheel, barrel, &c., that does not run true, clamp a piece of sheet brass in the dogs and turn out a sink that will exactly receive the wheel, &c., but allowing it to project slightly. Now unscrew one dog and advance it a little, so as to grip the edge of the object as well as the plate ; move the other dogs inwards in succession, and it will only remain to drill or true the hole with a suitable drill.

UPRIGHTING AND DRILLING.

412. When the lathe is provided with a loose poppet-head.—Let it be required to mark and drill a pivot-hole in a cock when the plate-hole is accurately centred by means of the pump-centre. Place the loose poppet-head E (fig. 1, plate VI.) in position on the lathe-bed, and mark the position of the hole with the point *i* of the runner *a* (fig. 3) as in an ordinary uprighting tool ; then, if the hole is to be very fine, make it with an ordinary pivot-drill or a "finished" drill (**333**) supported by the hollow end *v* of *a* reversed. This operation will be more conveniently performed if the mandril is held in the vice with its bed vertical.

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If the hole to be drilled is somewhat large, it may be drilled with the centre *p* (fig. 3) carrying a cylindrical drill, the bed of the lathe being, as usual, horizontal.

Some details in regard to upprighting and drilling have already been given in article **391.**

413. When the mandril is not provided with a loose-poppet-head—In such a case it is possible to upright and drill by using fine drills and marking points so formed as to take the place of the cutter. Or a stock may be made to receive drills, points, &c., and it may be well here to remark that stocks of the same form are convenient for receiving chamfering or sinking tools, such as are shown in figs. 1, 3 and 11 of plate IV., or at *k*, fig. 8, plate VI.

This stock is shown in fig. 9, plate VI. An inspection of E *c* will suffice to show its form, and it may be used for holding either a drill or a marking point, or a small hollow centre in which to support a pivot drill.

The following method should be adopted for securing accuracy in the adjustment of these stocks :—

There must be no shake of the stock in the tool-holder ; it is especially important to avoid any displacement during the act of clamping. If there is any reason for doubts on this point, drill a hole at the foot of the cutter in which an index, *y* (fig. 9), can be temporarily inserted ; any displacement can be detected by its deviation from a fixed mark. As a rule, however, there will be no occasion for doubt if the plate that is screwed down upon the stock is parallel to the bed of the tool-holder.

The cutter is then replaced by a stock of the form shown at E^1 (fig. 9), in which a hole has been previously drilled to receive the drill or other bit, but somewhat smaller than it is required finally to be. The pump-centre must now be replaced by an accurately fitting piece B that terminates in a short semi-cylindrical drill.

It will be evident that if the mandril be revolved and, at the same time, the tool-holder advanced towards this drill,

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the hole in the stock E[1] will be enlarged and smoothed, and its axis will accurately coincide with that of B. Any drill, chamfering tool, &c., that has been turned true will, therefore, on being inserted in the stock, prove to be strictly in the axis of the lathe. (See articles, **391, 501—3.**)

To drill a series of holes.

414. Mount on a stock similar to that just described a small frame carrying a drill-stock, as shown in fig. 11, plate VI. If this be fixed in the slide-rest in place of the cutter, it can be used for drilling a hole or a series of holes previously marked out, or, if the pitch of the transverse screw of the slide-rest is known (**401**), for a series of equidistant holes in a horizontal line.

When it is required to drill a series of holes in a circle, as, for example, in the escape-wheel of the pin escapement, bring the point of the drill on to the circumference and then proceed as when using the ordinary wheel-cutting engine provided with a vertical drill-holder, taking care to fix the face-plate by means of an index.

This index should have a means of slightly modifying its length, so that the point of the drill may always be brought into exact coincidence with the points that have been previously marked on the object.

It will be observed that, if the drill were replaced by a round milling tool, the U's of a cylinder escape-wheel might be polished or, indeed, cut, the concave ends of the teeth of the star-wheel in a Geneva stop-work could be corrected, &c. But it is unnecessary further to insist upon the many uses to which this form of tool can be applied.

To cut the teeth of a ratchet, minute-wheel, &c.

415. When the face-plate is divided on the circumference (**400**), it is easy to cut the teeth of an ordinary wheel, of a

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timepiece escape-wheel, barrel ratchet, to cut or true a star-wheel for the stopwork, &c. After mounting the wheel on a chuck and carefully centring it, replace the cutter by a small revolving cutter-frame after the model of that shown in fig. 12, plate VI.

The stock *d*, shown in both plan and elevation, carries a piece *c* at right angles, which has a slot cut throughout its length. In this slot a U-shaped support can be clamped by a nut in any position. The U portion forms a bearing for a cutter, such as is shown at *f* in the figure, and the axis projects so as to receive a ferrule for rotating the cutter by a bow.

It will be evident that, with such an arrangement, the height of the cutter can be adjusted in accordance with the teeth to be cut, and that it is brought up against the wheel by means of the screw D (fig. 2), the motion of the bow being uninterrupted.

To cut a circular or elliptic groove.

416. For this purpose no special accessory is needed; an ordinary cutter will suffice.

Let *a b c d* (fig. 3, plate VII.) be the form of the required groove. Mark a series of centres so that circles struck from them will just overlap one another, and at the same time nearly reach the edge of the groove. Then turn out all the circular sinks, indicated by shaded lines, to the required depth.

Centre the plate by the point *o* from which the arc *a b* is struck; now bring the cutter to such a position that its outer cutting edge coincides with the arc *a b*, and bring it against the plate; set the face-plate in motion, not, however, by using the handle, but by the hand at its circumference, and traverse the arc from *b* to *a*; then withdraw the cutter. By this means the projecting angles, left white in the figure, will be removed and a clean edge will be left to the groove.

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As an operation of this description will not present any difficulty, further explanation appears unnecessary; for the information above given will enable any watchmaker to make curved grooves of the kind indicated. (See articles **41—2.**)

If it is required to smooth the surface of the groove, replace the cutter by a pegwood stick that can be rotated with friction, and the end of which just fits into the groove, charging it with pumice or other stone and oil. One hand moves the face-plate backwards and forwards while the other rotates the stick.

417. *To cut the cylinder escape-wheel cock passage.*—As a rule the cock is cemented, inverted, to a wax chuck and the passage cut or enlarged on the mandril. It is more expeditious to use a plate provided with a clamping bridge as shown at A, fig. 10, plate VIII. The face-plate should be made to oscillate backwards and forwards by hand, and not rotated by the wheel.

To make a straight groove.

418. *First method.*—The tool devised by M. Chopard,* and shown in fig. 8, plate VI., is used for this purpose. As will be seen, it consists of a small lathe which is adapted to the slide-rest as follows:—

Two pins *a*, a^1, are planted in the top of the tool-holder, the cutter together with the plate by which it is clamped having been first removed. Holes drilled in the frame *f f*, fit accurately on to these pins, while a screw *h*, passing through an intermediate hole, affords a means of firmly fixing the apparatus to the tool-holder M.

This tool should satisfy the following conditions:—The arbor C should fit into the recess that receives a cutter, but without coming into contact with it; this arbor should be parallel to the bed of the mandril; and, lastly, the axis of

* Director of the School of Horology at Besançon.

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C should be a prolongation of that of H, fig. 2, which is indicated by *g* in fig. 8.

419. Having set this little appliance in position, trace on the watch-plate two lines indicating the directions of the sides of the groove as well as lines fixing its length. Now place the plate in the dogs, setting the point of the pump-centre anywhere on the line drawn along the middle of the groove. Turn the plate so that this line is horizontal, and fix it in any way that is convenient.

The arbor C carries a revolving cutter *k*, which can be changed as desired, and is held in position by the clamping screw *d*. Assume that the diameter of this cutter corresponds exactly with that of the required groove ; with one hand advance it towards the plate by means of the screw D (fig. 2) while the other hand works the bow rapidly, the cord being round the ferrule *b* ; a circular sink will thus be formed in the plate of the same diameter as *k*.

When this has been cut to a sufficient depth, the left hand is transferred from the handle D to *c* (fig. 2), by which the tool is moved parallel to the face-plate, and the cutter *k*, continuing its movement of rotation, will now cut, not with its extremity *i*, but with its sides. It will thus form a straight groove of any desired length.

420. The cutter is a three-sided prism, or it may have four sides with four cutting edges on the sides, and only one cutting edge at the extremity *i*. If it is preferred to retain only the two acting edges that start from either end of the cutting edge *i*, they may be made more acute, and the other pair reduced by means of a file.

421. *Second method.*—This is simpler than the one just considered. At the end of a rod G, fig. 10, plate VI., which takes the place of the cutter in the slide-rest, a plate *p* is fixed. A line is drawn across the face of this plate in such a position that, when G is clamped in the tool-holder, this line is horizontal, and in the plane that contains the axis of the pump-centre.

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Let it be required to cut a straight groove in the piece of brass *l*. Wax it to the plate *p* so that the axis of the required groove is over the line traced on the plate. Now fix G in the tool-holder and replace the pump-centre by a rod D, the extremity of which is formed into a cutter of a diameter equal to the width of the required groove; the rod D should be fixed in the hollow arbor by a screw in the position indicated by *b* in fig. 2. It is then only necessary to set the cutter in motion by means of the handle of the mandril with one hand while the other turns the handle D (fig. 2), forcing the piece *l* against the revolving cutter, until the requisite depth is attained. Then, by moving the handle *c*, the tool-holder travels parallel to the face-plate and the groove will be elongated until of the desired length.

422. The cutter may be of the form shown in fig. 8, or it may be as shown at *b* in fig. 10, since the movement is always in the same direction. The cutting edges are each formed by two small inclined faces, one pair of which is shown at *b*; they occupy half the diameter of the cutter. At the back of this pair the cutter presents the appearance of the lower half shown in the figure and *vice versâ*.

It will be evident that the two sides of this cutter will act while its motion is continuous in one direction.

Besides the numerous operations that can be performed on the mandril as we have hitherto indicated, it may be employed, if divided on the circumference, for tracing out angles, marking the crossings of a wheel, a balance, &c., and for other purposes, many of which are referred to in the course of this work.

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PRODUCTION OF INTERNAL AND EXTERNAL SCREW-THREADS, AND MAKING OF SCREWS AND FUSEES.

SCREW-PLATES AND TAPS.

423. The lathes employed in the manufacture of screws are of two kinds; those intended for polishing and, where necessary, modifying the form of screw-heads, much used by watch examiners and jobbers, and those specially designed for cutting the threads, which are mainly in use among mechanics.

Before discussing them, however, we will give some account of the screw-plates and taps in ordinary use.

424. Common hand screw-plates.—The use of these is much facilitated by providing a second plate perforated with holes of such sizes that a spindle which just passes into a hole of any given number will be of the size most convenient for forming a screw in the hole of the same number in the screw-plate. For a long time we have made use of two Latard screw-plates so made that a rod which would enter one hole without play was of the most convenient size for forming a screw in the next smaller hole but one (thus the plate perforated with plain holes can be replaced by a second screw-plate, or by using the successively larger holes on a single plate as gauges).

In order to form a screw that is clean-cut and even, with the least possible straining of the metal, the holes in the screw-plate should have notches cut as shown at F, fig. 3, plate VII.; they should be carefully hardened and well polished on each side of the notch, and this system is now even applied in the case of the smallest jewel screws.

425. Screw dies.—The ordinary plate in which notches

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are not cut at the sides squeezes up and strains the metal. This effect is less marked when separate dies are used, and disappears entirely if only a small quantity of metal is removed at a time, and the cutting edges of the dies are smooth and in good order. In addition to possessing other advantages this form of screw-plate enables us to obtain at will screws of the same thread and different diameters or of the same diameter and different threads. The dies must be carefully fitted to the slides that receive them. Dies cannot be employed for cutting very small screws.

426. Fine-threaded screw-plates.—At the present day these can always be obtained at the tool-shops ; but thirty years ago it was not so, and the watchmaker was obliged to make them for himself. The following method was adopted :—

Take a screw formed with an ordinary plate, in which the thread is broad as compared with the hollow. If the screw does not satisfy this condition it must be modified thus :—

Having ascertained that it runs true on its points, and that it is larger than will be ultimately required, attach a ferrule to the screw and place it between the centres of the lathe. The T-rest must carry a smooth horizontal rod of hardened steel.

Rotating the screw with a bow, hold a slitting file in the hollow ; the file should fit into this hollow accurately, and should be smoothed on its two sides, only cutting with one edge. The bar of hardened steel will determine the depth to which the file is allowed to cut. By this means a screw is obtained that has a thread thick at the bottom. With the graver remove the top of this thread, round off its corners, and harden the screw, filing three facets along its entire length, that make it taper.

The tap having been thus prepared is employed for cutting a thread in a piece of steel, not too thick, that has been previously annealed, and in which a hole is drilled of

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the proper size. The thread of this internal screw will be thin and the hollow proportionately broad.

The plate is now hammered cold with care until the thickness is so far diminished that the thread and hollow are as nearly as possible of equal thickness. Harden it and chamfer the ends of the hole with a conical steel point and oilstone dust. Then clean it and cut a thread on a piece of soft steel which may be formed into a tap.

If the operation has been properly conducted, this tap will satisfy the prescribed conditions, and, when hardened, it is to be employed to cut a thread in a second steel plate, which will be employed as a screw-plate ; for that first formed must, in consequence of the hammering to which it was subjected, present irregularities in the hole, and can only be used to cut one or two taps cautiously. It is useless for making screws or for tapping brass. (See also **430.**)

427. *To clear a stopped hole in a screw-plate.*—Drill a hole through the centre of the piece of metal that fills up the hole, taking care to maintain it central, and to employ a drill that is sufficiently small to avoid all risk of contact with the screw threads. Pass a broach through this hole and, after tightening it with a few gentle blows with the hammer, turn it in such a direction that it tends to unscrew the broken screw, which will, in nearly every case, be removed without difficulty by this means.

Or the tool described in article **370** may be used.

TAPS.

428. Screw cutting comprises two distinct operations—the formation of a spiral thread on the circumference of a cylindrical spindle and of a spiral groove within a cylindrical hole to receive this thread.

Taps are made either by means of a screw-plate or in the lathe ; we shall presently refer to this second method (**450**). Every watchmaker may be supposed to have received, early

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in his career, instruction as to the cutting of a tap with a screw-plate. Great caution is necessary in the hardening (**87**), for if the tap is not true or the metal burnt it will cut badly and be apt to break. Taps are cleaned after hardening with a piece of wood in the lathe or between two hard pieces of pith covered with oilstone dust, and either three or four cutting faces may be made. It is important to avoid the production of a burr in making these facets : a good plan is to make them while the metal is still soft, and to pass the tap through the plate subsequently, as a sharp cutting edge is thereby produced. The facets should be carefully smoothed, and the use of coarse rouge is an advantage.

A tap with three facets gives the cleanest cut and leaves the most space to receive the metal that is removed, but with four facets the roundness of the hole is more certain to be maintained.

We have seen taps formed as represented at M (fig. 7, plate XIII.), so that the object in which a thread is being cut is loose at the part *o*, when the direction of movement of the tap is reversed. They are also at times made semi-cylindrical as at G, and work well in the lathe for tapping brass, but we have not tried this form with steel.

429. To cut a tap when of considerable length.—The following precautions must be observed in order to ensure that a long screw shall be both round and true.

The steel must be of very good quality, and loose dies should be used in preference to a screw-plate. It is a good practice to employ two pairs of dies (or even more): one to rough out the screw, leaving the thread somewhat larger than it will finally be, and the other to finish after having trued it, and even sometimes lightly turned the surface in places. Very little metal must be removed at a time, the dies should have sharp cutting edges, and a rather large number of threads.

The turns can be used for cutting the thread if provided

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with an arrangement such as is shown in fig. 6, plate IV. Or a screw can be made in the ordinary manner in a screw-plate rather larger than is required, then reduced to the requisite diameter, and finished with a plate in which the holes are of the form shown at F (fig. 3, plate VII.), or in a screw-cutting lathe : in either case, however, care must be taken to avoid straining the metal in its passage through the first plate, on account of the tendency which it then possesses to become distorted in the hardening.

If a micrometer screw is required, that is, a screw of absolutely uniform pitch, it is necessary to apply to makers of astronomical and other similar instruments of precision.

430. To cut a screw of any desired pitch and diameter.—Let it be required to cut a thread on the stem B (fig. 1, plate VII.), of any pre-determined pitch that already exists in a screw-plate. Turn down the portion *d* to such a diameter that a screw can be cut on it in this hole, and fit two runners to the lathe of the form shown at G and H. The end of H is drilled and tapped so that *d* turns freely in it and a hole is drilled in G to receive the stem B freely, but without sensible play, and a fine notch is cut at *a*.

It will be obvious that if now the ferrule *r* is caused to rotate by a bow while a fine saw or file is inserted in the notch *a*, a screw will be formed on B of the same pitch as that on *d*, although there may at the same time be a very considerable difference in their diameters. This method may be adopted in place of that explained in article **426** for obtaining a fine-threaded screw.

431. Left-handed screw taps.—The manner in which these are made in the screw-cutting lathe will be subsequently explained ; in its absence the watchmaker may adopt one of the following methods :—

First method.—If, when an internal screw has been cut with a right-handed tap, B (fig. 4, plate VII.), it be required to tap a second hole in the reverse direction, the following plan may be resorted to :—

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File the original tap B on two opposite sides so as to give it the flattened shape shown at A in the same figure. Insert the end into the hole to be tapped and turn the tap towards the left with the application of considerable pressure so as to force the tap to bite. When the tap has been passed in and withdrawn there will be found to be a left-handed thread cut in the hole. For, if the tap is turned towards the right, the thread *f* passes into the groove already formed by the thread *a*, &c.; but, if turned towards the left, *f* will originate a groove into which *b* will pass, travelling in an inverse direction to that previously given to it.

The finer the thread of the screw, the better is the chance of success, and with a wide thread it is often necessary to re-commence two or three times. If a plate or pair of dies be cut in this manner and hardened, they will serve to cut an even left-handed tap.

Second method.—Attach a comb to one or two sides of a cylinder, as indicated at F (fig. 5, plate VII.). This can be used to cut a thread in the piece of metal S, that is either right or left-handed according to the direction of rotation of F, sufficient pressure being at the same time applied to force it into the plate. The pitch of the thread will depend on the amount of pressure applied. This plan is only a modification of the one described above, and, as in that case, success can only be guaranteed when a means is adopted for securing a definite relative amount of motion in F round its axis and S vertically.

Third method.—A tap of unhardened steel is filed into a triangular form (C, fig. 10, plate VII.), and twisted so as to bring the angles *b*, *f*, towards *a*, *d*, &c.; we thus obtain a tap which will serve, throughout a certain portion of its length, to cut a left-handed thread, but the part that is not so adapted, at the extremities, will require to be removed before hardening.

432. *To make a left-handed tap by means of a right-handed tap.*—A portion of the right-handed tap is filed off

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on three faces to the section shown at *b* (fig. 6, plate VII.), and firmly set in the die *d* so as to be held in the frame for screw-cutting dies. A second die *f* made of brass and having a semi-cylindrical recess opposite *b* is fitted to the frame. The diameter of this semi-cylinder should be the same as that of the rod on which a left-handed thread is to be cut. Now grip this rod as shown at *a* by means of the screw *g*, so that it is held between the die *f* and the block *b*, and rotate the frame or the rod *a* towards the left; a spiral groove will thus be cut by the thread on *b*. It is sometimes an advantage to cut this thread lengthwise in the manner indicated at b^1.

This method enables us to cut a given thread on a rod of any diameter. From an examination of figs. 4 and 6, it will be seen that a simple comb of the form C or D, carefully made by hand and fixed in the place of *b* (fig. 6), can be employed to cut a right or left-handed thread on any given rod; it is advisable, however, that the teeth of the comb be inclined to the axis of the screw, like the thread of an ordinary tap, as otherwise the operation becomes more difficult and success less certain.

The method may be simplified by taking a brass plate, D (fig. 10), of sufficient thickness, and firmly setting in it the right-handed tap, *v*, having only filed away two opposite faces before hardening. The rod to be tapped is then introduced with considerable pressure into the hole *j*, and, if rotated towards the left, it will receive a left-handed thread of the same pitch. The notch shown at b^1, fig. 6, will facilitate the operation, as a cutting action will take the place of compression.

433. M. Gontard has suggested a modification of this arrangement, which consists in forming the die *f*, fig. 6, so that the original right-handed tap can be embedded in a hole previously tapped in it and filed away on the side towards *b* so as to expose a cutting edge; and he points out that, by suitably inclining the frame with reference to the

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axis of the rod to be tapped, the appliance can be used to cut a double or even a triple-threaded screw, right or left-handed. He further draws attention to the fact that in a screw formed in this manner the sides of the thread are smooth and polished, a condition which cannot be secured when either a plate or dies are used.

434. To increase the diameter of a tap.—It sometimes happens that a screw will not penetrate to a sufficient depth or fits too tightly into its hole, owing to the tap employed being of a less diameter, either in consequence of the hardening, polishing or wear, or through having been formed in a different screw-plate. In such a case the following expedient may be resorted to :—

Make a fresh tap in soft steel and file away two opposite sides so as to give it the section shown at A or B, fig. 5, plate VII. : after measuring the diameter at several points in its length, hammer gently on the flattened sides. With a little care and by using a micrometer at intervals for testing the alteration in diameter, it will be found that the required increase can be obtained without much difficulty. The tap is then hardened and polished, &c.; indeed, it is best to make a fresh tap in the manner explained in par. **267.**

METHODS OF TAPPING HOLES.

435. It is needless to refer to the method of tapping by hand, as it is well known to all practical men (see **289**).

436. Tapping in the mandril.—The plate of a watch is gripped in the dogs of the face-plate, the hole to be tapped being centred by means of the pump-centre, which is then withdrawn, and a tap held to the hole ; the face-plate is then caused to rotate either by the hand resting on its circumference, a slight backward motion being given after each advance, or the motion may be continuous and given by the handle. In the latter case, however, the tap must have a good cutting edge and only be held in the hand

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with the degree of force required to make it cut, so that it may rotate without breaking in case the resistance opposed becomes too great.

The tap may be steadied on the T-rest, or the following plan, which is equally applicable with other forms of lathe, can be resorted to. Mount the tap in a spindle that traverses the hole *d v* of the loose poppet-head E, fig. 1, plate VI., either adapting it as a runner or of the same diameter as a hole in a collar fitted into either end of *d v*.

It will be obvious that, with such an arrangement, it is possible to tap in the ordinary way, maintaining the plate stationary with one hand while the tap is rotated with the other. Indeed, the inertia of the plate is often sufficient without holding it.

As with the succeeding methods, a certain number of preliminary trials will be found necessary.

437. To tap with a mainspring winder.—The ordinary mainspring winder will, if the click work is removed, be found very convenient for tapping holes, and, indeed, for forming the external thread on screws. Having removed the winding arbor, replace it by a tap carefully centred; then introduce its coned end into the hole in the plate which must be pressed forward while the handle is turned, a short backward motion being given to it at frequent intervals. When the tap is engaged sufficiently in the hole it is merely necessary to maintain the plate at right angles without applying pressure.

438. To tap with a bow.—Instead of the mainspring winder, one of the small drill-stocks to be driven by a bow, consisting of an arbor, with a coned hole at one end and ferrule at the other, supported in a frame that is clamped in the vice, may be used. They are to be obtained at any tool-shop.

The bow being on the ferrule and the tap properly centred in the arbor, the hole is held against the coned end and the bow worked with an alternate forward and backward motion

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similar to that of the handle when the mandril is used; but if the tap has a good cutting edge and the bow is strong (of steel or cane), a hole may be tapped with a single stroke of the bow. After a few trials the method will be found very easy and certain.

A regular and rather slow motion should be given to the bow, which should be long and strong. It is well to ascertain the number of revolutions of the ferrule that correspond to a stroke of the bow, so as to ensure that the tap is not introduced to a greater depth than is required. If it is desired that the screw work easily in the hole, the tap should be moved several times backwards and forwards.

439. The little turns here referred to, some of which are perforated throughout their entire length and others only at one end, are very cheap and will often be found useful; they can be adapted to receive drills, broaches, taps, &c.

440. To tap in an ordinary lathe.—In factories it is a common practice to tap the holes in plates, &c., and even to cut the threads of screws in a lathe specially arranged for the purpose. The tools adapted for such work are of two kinds: in some the tap enters to the required depth, when it is immediately arrested, disconnected, and then rotated in an opposite direction; in others, the tap advances to a definite point, and is immediately withdrawn. As a rule, however, the tap remains stationary and the object is caused to rotate.

441. Beillard lathe for tapping screws.—The axis F *m*, fig. 10, plate XIII., is perforated throughout its length. At F, the screw-plate G is dovetailed into it. The inner end of the hole in this plate is slightly coned to facilitate the insertion of the brass wire D, and it must be exactly in the axis of F M. A guide B sliding on two rods *c*, *c*, is traversed by the rod D which can be clamped in it by the screw *a*.

By pushing D against the screw-plate at the same time that the handle N is rotated, a thread will be traced on it

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and it will emerge at *k*. When B has advanced to the point *m*, the screw *a* is released, B is drawn back, and *a* again clamped.

When a long screw, such as X *x* has to be tapped, the screw-plate is fixed at *m*, and the guide B fastened on to the portion X. Of course the hole in the screw-plate must always be abundantly provided with oil.

If the screw-plate F is replaced by a plate perforated with a round or square hole, a drill, broach or tap may be substituted for *k*, being clamped by the screw *h*, and the tool is at once available for drilling, broaching or tapping any given hole.

RAPID MODE OF MAKING A SCREW.

442. The methods ordinarily adopted by watchmakers are too well known to need description; we will therefore at once proceed to give a special plan recommended by M. Vissière.

An excentric poppet-head with boring-plate (fig. 8, plate VII.) is fitted to the bed of the lathe, the excentricity being such that the axis of the centres is at the point *a* on the circumference of the circle *a y*. The conical hole, having a centre at *a*, is cut away towards the rim of the plate to the degree indicated in the figure, and its centre is so placed that the vertical line *f* and the radius *d* are inclined at about 120°. The position of the T-rest is shown at *s*, and by bringing it into actual contact with the disc the steadiness of both is increased.

The fixed headstock of the turns is provided with a runner of the form B, fig. 7, plate VII., terminating in a point *m* at one end and a hollow cone or funnel *n* at the other end.

Having filed the ends of a rod T, of any required diameter, square and fitted a ferrule, support it between the two cones, *a* of the boring-plate and *n* of the runner. Near

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the end *a* cut a hollow *r* sufficiently small to allow the stem to pass through the notch in the hole *a* (fig. 8). After passing it through, the rod will be supported as shown at H (fig. 7), so that the rim *e i* rests against the cone.

Further explanation is hardly necessary; after removing the portion *c g* with a graver, turn down to a point *p*. When making a screw turn out a second hollow *o o*^{1}; it then only remains to turn off the disc at the extremity, and the screw will be roughed out of the form *c p g v*.

If it is preferred to work with a point at the left-hand end of B, remove the rod after the point *v* has been turned, replace *m* B *n* by a common runner, reverse B, and recommence the operation.

It would be difficult to devise a method for roughing out a screw and making a point that would be more expeditious than the one here described.

443. *Another method.*—Another convenient mode of roughing out a screw consists in applying a rose-bit against the extremity of the rod, in a lathe arranged in the manner shown in fig. 10 on page 212. The bit has teeth formed at the flat extremity, and is perforated with a hole through its axis of a diameter equal to that required for forming the screw, and funnel-shaped backwards; it is then hardened and tempered to a straw colour (**88**). Being adapted in any convenient manner to the end of the runner, the lever is used to press it against the extremity of the revolving rod carried by a chuck fixed to the lathe-head. The screw is thus roughed out of the form shown at X *x*, fig. 10, plate XIII., of course without the thread.

SCREW-HEAD TOOLS.

444. These are of various kinds: some work by hand and others by a bow. The jaws are brought together sometimes by a sliding ring, and at others by a milled head placed between them and rigidly attached to a pin tapped with

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right and left-handed threads that engage in the jaws. But neither of these plans is good; the screws are not held firmly and they are rarely well centred, owing to the slight displacements of the jaws. The English screw-headed tool is a simple lathe, somewhat of the form shown in fig. 2, plate III.

A better plan is to arrange, either in the lathe or in the jaws of the screw-head tool (when driven by a bow), a series of chucks of the form shown at T, fig. 9, plate VII. They are easily made and tapped, the hole *i* serving to remove the metal from the inner end of the hole that has to be tapped; such chucks occupy very little space, and, if numbered to correspond with the size of screw, any chuck required can be found without trouble. If the hole becomes too large owing to frequent use, a larger size of tap can be passed through the hole and its number changed.

445. A set of such chucks is almost indispensable at the present day to the watchmaker who wishes to repair watches well; for he rarely makes his own screws, as they are to be obtained well made and very cheap at the material-dealers, whereby a great saving of time is effected. But their heads are seldom of the proper size to fit the original sinks, and by being provided with such a series of chucks the watchmaker can at once overcome this difficulty, as he can turn the heads down with a graver.

446. R, fig. 9, plate VII., is an arbor for a screw-head tool that is driven by a bow, and is adapted to receive such chucks, or it can be used in an ordinary pair of turns, *d* being supported on a pointed centre, and *g* in a boring-plate (fig. 4, plate II.), or in a cone-plate centre (**255**).

447. In this form of screw-head tool the portion A is sometimes perfectly cylindrical, so that the piece V can slide on to it, being clamped by the screw *b*.

This tube V is cut away through about half its length with a notch, as indicated in the figure; bent pieces of hardened steel *c* and *n* are screwed to either side of the

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notch. Screws, *h* and *f*, provided with lock-nuts, determine the distance between these plates, and when V is in position on A the ends of *c*, *n*, will rest on the screw-head, leaving just sufficient space between them for inserting the file that cuts the slit.

Hard steel caps of the form shown at M may also be fitted to A, a notch being cut in them to receive the screw *b*. These will be found useful as guides for filing or polishing screw-heads, or the ends of arbors flat, reducing the heads of several screws to the same height, &c.

448. The tool for forming the U-spaces in a cylinder escape-wheel* can easily be converted into a screw-head tool with laps. A glance at fig. 11, plate VII., will at once make this evident. A number of chucks are adapted to the arbor A, and in the tube *c c* either a T-rest or a spindle carrying a lap is fixed.

It will also serve as a tool for drilling (see article **306**); a drill-chuck with drill, *f*, being adapted to A, and the object to be perforated at *b* resting against a plate that projects at right angles from a slide *d d*, which may be advanced by a screw *g*.

449. *Simple form of screw-head tool.*—An ordinary pair of turns is provided with two runners that terminate in arms set at right angles, *d c*, *b f*, fig. 9, plate XIII. The spindle T, rotating in conical holes *a* and *c* in these arms, has its ends drilled with holes in the axis, and tapped so as to receive screws in the manner shown at *c*. It is obvious that when a bow cord is passed round T and the T-rest clamped on the bar P, it will be easy to file, turn, or polish the head of a screw *n*.

If the spindle is made from three to four inches long, it can be conveniently held in the hand for cutting the slit, &c. When a hole becomes too large drill it deeper, tap it afresh, and turn off the useless metal at the end. By making a

* See *Treatise on Modern Horology*, p. 278.

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collar of the form x, fig. 2, plate XIII., that the spindle T will fit without much play, the screw-head may be polished flat on a sheet of ground-glass.

SCREW-CUTTING LATHES.

450. Fig. 14, plate VII., is an ideal sketch to show the principle of the modern screw-cutting lathe.

The pulley *p* communicates motion to the spindle *v*, on which a thread has to be cut. This spindle carries a wheel *m* that engages with a second wheel *n* fixed to the longitudinal screw of the slide-rest. It will be evident that when *v* rotates, the tool-holder will be displaced laterally and the tool will trace a helical groove on the circumference of the spindle. The motion can be obtained in the manner explained above, or by a handle on *v* prolonged, or on the longitudinal screw of the slide-rest.

It is to be observed that, when a right-handed thread is required, the screw that impels the tool-holder should be left-handed in an arrangement such as is indicated in fig. 14, and conversely. The pitch of this leading screw must be accurately known; it may be determined by measuring with great care, either by a dial micrometer or a vernier, the interval between the middle points of any two threads, an interval which then has to be divided by the number of turns of the screw that are comprised between the limits taken: the result is the pitch of the screw.

Suppose this to be 1 millimetre: it follows that, if the wheels *m* and *n* are of equal diameter, the cutter will be displaced 1 millimetre for each complete revolution of the spindle *v*; when the number of teeth on *n* is half that of the wheel *m*, it will be displaced 2 millimetres, and, in the converse case, half a millimetre. Thus the pitch of the thread cut on *v* will be, in these three cases, 1, 2 and $\frac{1}{2}$ a millimetre respectively.

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Let R be the radius of the pitch circle of the wheel *m*,
„ *r* „ „ „ „ *n*,
„ *p* „ pitch of the longitudinal screw of the slide-rest,
„ P „ pitch of the screw to be cut on *v*.
Then

$$P = \frac{R\ p}{r}$$

or, in other words,

$$P : p :: R : r.$$

Thus the pitch varies directly with the radii of the wheels.

To cut a screw of any given pitch it is, then, only necessary to select suitable wheels, and the second part of the *Treatise on Modern Horology* furnishes all the information necessary for this purpose.

It is to be observed, however, that fig. 14 does not represent the actual arrangement it is most convenient to adopt in practice, for an account of which the reader must be referred to works treating of Mechanical Engineering,* but it serves to explain the principle on which screw-cutting lathes are constructed.

TO CONVERT THE ORDINARY TURNS INTO A SCREW-CUTTING OR FUSEE-CUTTING LATHE.

451. Fig. 12, plate V. (described in par. **300**), represents a pair of turns to which a slide-rest is adapted, and in fig. 13, plate VII., is given a section of the side, E, of the frame with the modifications that are needed in order to trace screw-threads by its means.

The handle of the screw *v* is replaced by a wheel *c* firmly fitted on to a square. A second wheel *d* is mounted tight

* For example, Holtzapffel's *Turning and Mechanical Manipulation*, Vol. IV.

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on the runner *b* (which supports the end of the rod *t* to be formed into a screw), so that it can only rotate with this runner. At the end of *b* is fixed a driver *j* that communicates motion to *t* by means of a carrier: it has a shoulder to prevent the runner moving longitudinally in the frame E, and the outer end of the runner is provided with a handle.

It will be evident that, if the pitch of the screw *v* is known, a thread can be cut on *t* that is either equal, greater, or less by properly proportioning the wheels *c* and *d*.

452. *Remark.*—The screw *v* must be left-handed if a right-handed thread is required on *t*, when the arrangement is as above described; but the same screw can be used for cutting either right or left-handed threads by using, in the one case, two wheels *c* and *d*, or *g* and *h*, and, in the other case, two wheels *q* and *s*, with an intermediate idle wheel *x*: with the former arrangement the thread cut will be the converse of that of the leading screw, and with the latter it will be the same.

TOOL FOR CUTTING FUSEES AND SCREWS.

453. In order to adapt the tool which has just been described to cut and true fusees, it will only be necessary to suppress the transverse screw of the slide-rest, *s*, fig. 12, plate V., and to apply a lever, *l*, fig. 12, plate VII., by which to advance the cutter to or from the work. The extent of this motion is limited by a screw *i b*, carried by the slide, coming in contact with a hard steel guide *i j*, screwed to the cross-piece *z z*: this must be rigidly fixed to the two sides of the frame E E, fig. 12, plate V.

The piece *i j* is a template giving the profile of the fusee, and the degree of penetration of the cutter is determined by *i b*, which is maintained stationary by means of a lock-nut *o*. If the template *i j* were a straight-edge parallel to the bed of the lathe, an ordinary screw would be cut, and, if it were inclined, we should obtain a conical screw.

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The cutter should only be in contact with the work while in the act of cutting ; if the rotation is in the reverse direction, it must be drawn away. The entire apparatus requires to be firmly made, and to work freely but without shake.

TOOLS FOR CUTTING AND ROUNDING-UP THE TEETH OF WHEELS.

WHEEL-CUTTING ENGINE.

454. The machine for dividing the circumference of a wheel, termed the wheel-cutting engine, and one form of which is shown in fig. 17 on page 295, is well known to nearly all workmen. The wheel is fixed to a chuck at B by wax or screws, or by the pressure of a hollow cone or "sugar loaf" of steel, to the apex of which pressure is applied by the arm D, or in other ways. The wheel may be centred either by a pump-centre within the chuck or by an appliance such as is shown in fig. 2, plate VII., except that the arm *b* is curved and its index much longer. This little addition may be fixed to the frame of the engine in any convenient position.

The chuck B that carries the wheel is rigidly connected with a large brass plate A A, on which are concentric circles of divisions, and the whole can be maintained stationary by setting the point of the index C C in any desired hole on the division-plate. The cutter is carried on an arbor (shown separate at L) between horizontal bearings in the frame J, and is caused to revolve by means of the pulley K. The several parts lettered E, F, G, H, are for bringing the cutter against the wheel and modifying the direction in which it moves, so that the machine can cut straight or inclined teeth, bevel or crown wheels, &c. It should be added that the engine here represented is more complex than those

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ordinarily used for cutting watch-wheels, although the principle on which it acts is the same.

The teeth may be cut by circular cutters of the nature of files, by a small straight cutter, similar to those used in a slide-rest, projecting from a rotating axis, or by several such

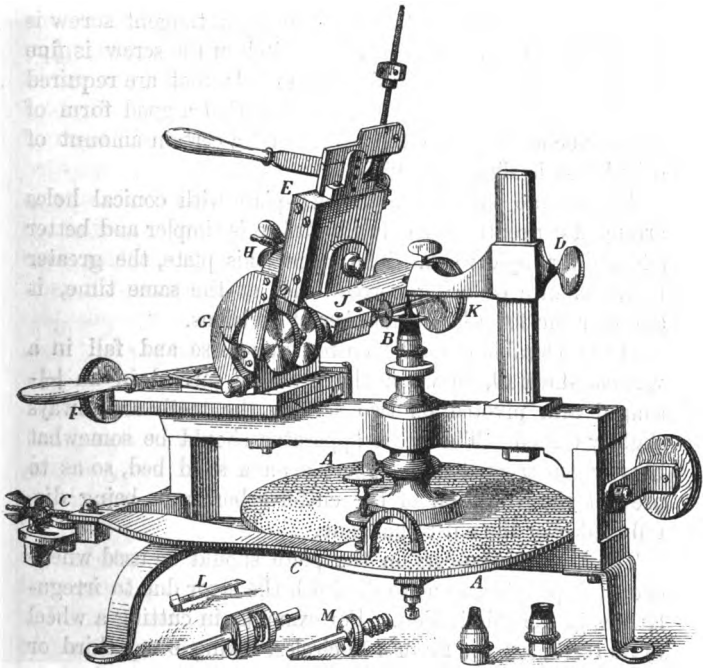

FIG. 17.

cutters mounted on a disc which is caused to rotate. For the sake of distinction it will be well (**464**) to refer to the first of these as *file* or *mill cutters*, while the second and third may be termed respectively *single* and *multiple blade* or *composite cutters*.

Watchmakers rarely possess a sufficiently large assort-

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ment of file-cutters for making all the various forms of teeth that are met with in horology; but this deficiency can be supplied by making them for themselves to any required pattern in the manner subsequently described (**464—491**).

455. *Observations.*—The wheel-cutting engine in which the plate is caused to rotate by means of a tangent screw is usually the most accurate. If the pitch of the screw is fine it will give all the subdivisions of a circle that are required for ordinary work, but it is essential that a good form of counter be attached to the screw, and a certain amount of calculation is always needful.

The engine that has a division-plate with conical holes arranged concentrically over its surface is simpler and better adapted for rapid work. The larger this plate, the greater is its chance of being correct and, at the same time, it affords room for a larger number of divisions.

It is preferable that the cutter frame rise and fall in a vertical dovetail, for when the arbor is carried in an H-shaped arm pivoted on two screws, the teeth are always slightly dished. The entire apparatus should be somewhat heavily constructed and supported on a solid bed, so as to prevent the vibration of the cutter-arbor from being distributed over the entire machine.

The highest numbers on the plate should be used whenever it is possible, so as to diminish the error due to irregularities in the subdivision. For example, in cutting a wheel of 30 teeth, use the 90 or 120 circles, taking every third or fourth hole (see par. **400**).

These remarks will probably be sufficient to enable any watchmaker who possesses a wheel-cutting engine to employ it with success; we will, however, add the description of a few appliances or processes that have a bearing on this question.

456. To divide a wheel so that it has one tooth more or less than any given number on the division-plate.—

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It is to be observed that neither this nor the following method is mathematically exact, but, if it is practised with care and the division-plate is of sufficient diameter, the error may as a rule be neglected.

Let P, fig. 1, plate VIII., be a division-plate that has a 30 circle, but not one of 29 or 31 divisions. Divide the circumference of a disc *d*, seen on edge, into a large number of parts in the engine, 360 for example, and fix it to the end of the index, at the same time attaching a finger, *i*, to the support *s*. Now advance the screw of the index through a distance corresponding to the angle *l* P *k* included between two successive points of the 30-division circle. To measure this distance a pointer should be previously fixed to the frame to correspond with the middle point of a hole in the circle under consideration, and the motion should be arrested when it coincides with the next succeeding hole. Assume that this amount of displacement has required three complete turns of the screw ; 1,080 divisions on the disc have thus passed under the finger *i*. Dividing this number by 31, we obtain 34·83.

After observing the division on *d* that coincides with the pointer *i*, cut the first space of the wheel ; then cause 34·83 divisions to pass under *i*, in such a direction that the plate is drawn with the arrow, and transfer the index to the next hole of the circle, rotating this time opposite to the arrow ; the second space can now be cut, and so on.

With a view to diminish errors arising from the omission of fractions, since 31 does not divide evenly into 360, a number of multiples of the number 34·83 should be determined. Thus 4 times 34·83 is 139·32, so that, when the fourth space is cut, the pointer *i* must be at this number of divisions from its initial position.

The index should be so situated that, when half the arc *l k* has been traversed, as explained above, *s a* is at right angles to the radius P *r* of the division-plate. If it is desired to move *d* in a reverse direction, it must be moved

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backwards to a considerable distance and then forwards up to the required point so as to avoid error due to backlash. The screw of the index should fit the support *s* firmly and without any shake.

457. To cut a wheel with any given number of teeth.—When the given number does not occur on the division-plate, proceed as follows :—

Take a strip of metal, for example a pliant piece of soft steel, and cut in it a series of equal and equidistant notches as shown at B, fig. 2, plate VIII. Cut the band to such a length that it has the same number of pairs of teeth and spaces as the wheel is required to have teeth. Now turn a lead disc of a diameter that the strip of metal will exactly enclose ; fix this strip round the circumference with pins, screws, or in any convenient manner, as is shown at C. We thus obtain a temporary division-plate which can replace the permanent one or be attached to its upper or under surface, and, when an index has been adapted to it, the wheel can be divided into the requisite number of parts.

When employing an engine the division-plate of which is worked by a tangent-screw, the above affords an easy means of making the divided head for the screw with any desired number of divisions.

458. With a view to ensure accuracy, it is advisable to employ a disc of large diameter as the errors of division are thereby rendered less important and the metallic blade can be made to lie closer to the rim.

The blade is subdivided by a saw to which a guide is attached, as indicated at H, fig. 2, plate VIII.; or the saw can with advantage be replaced by a file that only cuts on its edge and not on either face, or by a pair of mills or revolving cutters united together as shown at S. The following plan however appears to be more expeditious and to involve less trouble to ensure accuracy.

A hole *a*, fig. 3, plate VIII., is drilled in a metallic band

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by means of a semi-cylindrical drill fixed in the chuck of a mandril or in a wheel-cutting engine, &c. It will be convenient if the drill can be set vertical. Beneath it is a brass bed-plate in which are fixed two pins equal in diameter to the hole *a*; this hole having been placed over one pin *b*, the band is held firmly against the other, while the second hole is drilled. This is then transferred to the pin, and so on.

In the absence of a suitable tool, a well-made measure can be employed for marking a series of points with the aid of an eyeglass; the holes are then drilled with the bow or in any other manner.

459. To cut a wheel, ratchet or pinion on ordinary turns.—When only a moderate degree of accuracy is required, the ordinary turns can be adapted for cutting the teeth of minute-wheels, ratchets, pinions, &c., by making the following appliance.

The piece B, fig. 6, plate VIII., provided with a stud at *p*, slides on two horizontal and parallel cylindrical rods fixed to the slide C, or it may move in a dovetail. The cannon *d* carrying a ferrule *k* and a file-cutter *f* rotates on the foot at *p* without shake; and the cord of a wheel or bow passes round *k*.

R, the wheel to be cut, is supported between the runners, the divided plate V, which may even be an old wheel with the required number of teeth, being fixed to the axis of R. V is held stationary during the operation of cutting, by the index *l*. The mode of action hardly requires explanation: while *f* is rotating, advance B until it is arrested by the stop *t*; then draw B back, advance *l* to the next division on the plate, and so on.

460. We have said enough on this subject to enable any watchmaker to make such a tool, modifying it or completing it according to his requirements. We would only remark that: (1) if a cannon of the form *d* is used, the stud should be diminished in diameter as its middle part for about three-quarters of its length, so that friction occurs only at

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extremities; and (2) if a wheel is used to rotate *k*, there should be an idle pulley at *m* supported on a fixed arm independent of B, either attached to the lathe-bed or bench, or fixed in the vice, so that the ferrule *k* can move backwards or forwards without altering the tension of the cord, in the manner indicated at Y.

461. Wheel-cutting arbor-chucks.—These appliances are specially useful in making wheels that are required to be rigorously true, such, for example, as escape-wheels. The form is represented in fig. 4, plate VIII.

It is simply the arbor of an ordinary lathe formed in two pieces, *b a* and *b c*, the body *d b* being very accurately fitted into the conical hole in the plate of the wheel-cutting engine. If now a wheel is fixed with wax on the extremity *z* and turned in the lathe to the required form, it is only necessary to unscrew *b c* and introduce *b d* into the socket of the wheel-cutting engine; then, having cut the teeth, the piece *b c* is replaced, and the whole is set in the lathe, if required to test its truth, without the wheel having been displaced from the chuck.

It will of course be evident that the two parts must be accurately fitted together; the tapped hole and the screw must be true with the axis. M. Millot, with whom we have seen this form of arbor in use, has not been able to detect any excentricity, although he often employs them.

462. They might be formed in one piece as *a d b* with a point at *p*. A boxwood ferrule is then fitted on to the portion *b d*, where it is clamped by two screws, and these can be released when it is desired to insert the chuck into the wheel-cutting engine. The points of these screws should be received in recesses in order to avoid the production of any roughness on the surface of *b d*.

Wheel-cutting engines have been made to receive these arbor-chucks without removing the pulley. The point *c* is placed in a hole and the upper end is enclosed in a collar which is tightened by means of a screw.

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The arbor used by M. Millot had a lantern chuck, and this is very convenient in making objects that require to be measured during the progress of the work.

See also the remarks in paragraph **270.**

463. Modification of the ordinary arrangement for holding the wheel while cutting.—In the wheel-cutting engine as usually met with, the wheel (when not mounted on an axis) is held against the chuck by hollow steel cone on which presses an arm that slides on a vertical pillar and can be clamped in any position. The hole at the end of this arm does not always, therefore, correspond with the point of the cone, and, as a consequence, the wheel often gets displaced during cutting. This inconvenience can be avoided by adopting the following device which we have een in use with several watchmakers :—

The pillar with its sliding arm is replaced by an iron or steel piece of the form G, fig. 9, plate XI. The point *a* is received by the central hole at the lower end of the division-plate axis, while the screw *b* presses on the point of the cone, clamping it firm. Further explanation seems unnecessary ; we would only add that the piece G must be made strong and perfectly rigid.

CUTTERS FOR FORMING THE TEETH OF BRASS WHEELS.

464. For making the teeth of the wheels of a train, a special form of cutter, set to revolve on an axis, is employed, and it may be constructed on three distinct systems.

(1.) A single cutter mounted on an arbor as at A, B, fig. 7 and 8, plate VIII. ; this may be termed a *single cutter.*

(2.) A circular cutter formed of a series of such single cutters, which will be termed a *multiple blade* or *composite cutter.* Two specimens are shown at F, J, fig. 11.

(3.) The pinion or steel-wheel cutter or mill formed of a single piece of metal, as seen in figs. 20, 21, and 22. These may be described as *mill* or *file cutters.*

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465. To make a single cutter.—The form shown at A, fig. 7, is roughed out to as nearly as possible the required form in good steel. Some makers possessed of exceptional skill make them entirely by hand, and they make very beautiful teeth by their means; but as a rule watchmakers cannot look for such success, so that it is better to complete the formation of the cutter in a specially arranged tool.

The two sides may be made in the wheel-cutting engine, with the same mill cutter, which is inclined when used to undercut the acting edge; but this operation is not as easy as it appears at first sight, and the watchmaker will find it to his advantage to make the following device :—

A spindle *b d*, fig. 19, plate VIII., supported between the runners, *t*, *v*, serves as an axis for the arm *f g h*, which is bent at *g* so as to afford a support to a conical cutter *a*, driven by a bow on the ferrule *c*. The descent of this arm is limited by an adjustable stop, fixed to the bed of the turns.

Having removed the T-rest, replace it by a rod N, to which the cutter is clamped by a screw *k*, after being roughed out so as to reduce the work required of the cutter.

Place N so that the conical cutter occupies the position indicated at *z*, and, if a slight pressure be applied at *h* while *a* is caused to revolve by the bow (although a wheel is better for such work), both the straight and curved portion of the side will be formed, and the side will, at the same time, be bevelled to an angle corresponding with that of the cone. The curved portion of the side will be more or less under-cut according as the arm *h* is depressed below the horizontal plane passing through the axis of the turns. The opposite side is formed by inverting the piece *f g h*.

The conical cutter should be so formed that it acts during the downward stroke of the bow, because, when a bow is employed, it is essential that the arm *h* be raised so as to bring the cutter out of action before raising the bow; the back faces of the teeth should never be allowed to cut.

In smoothing or polishing it is only requisite to replace

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the cutter by a smooth conical roller, and to work the bow and the arm *h* as before.

466. The cutter is sometimes fixed in the arbor as shown in fig. 7. The arbor itself is thick and perforated with a round hole in which the tail of the cutter accurately fits, a slight pressure applied by the screw *m* being sufficient to make it steady.

For cutting the escape-wheels of clocks the arbor should have a velocity of about 200 turns a second.

M. Peupin, a skilful watchmaker who adopts the practice here given, having observed that with a sharp cutting edge he did not obtain a sufficiently smooth surface, succeeded in obviating the difficulty by drawing a polisher with rouge along the cutting edge, maintaining it at right angles to the plane of the cutter. This operation, if carefully executed, will serve to remove the feather-edge, to make the edge even and yet not dull, and to secure a highly polished cut surface. The sides of the teeth will present a proportionately better surface, according as the portion *c a* (M, fig. 7, plate VIII.) approximates towards the dotted line *c d*.

His escape-wheel teeth are cut in successive stages. The last stroke of the cutter is given by advancing it against the side of the wheel, so that the cutter axis remains in the plane of the wheel (**472**).

467. Triangular cutters.—When a cylindrical or conical mill is not available for finishing and sloping the sides of a cutter, it may be replaced by a triangular cutter (T or C, fig. 23, plate VIII.), and when the application of much force is required there may be a pointed bearing; but this is seldom necessary.

If carefully hardened and set, such a cutter gives a clean cut; of course it will not act for as long a period as the conical form above described, but this is of comparatively little importance, since the blank cutters are always roughed out previously to nearly the requisite shape.

468. To make several cutters at once.—By adopting

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the following method, it is possible to make several such cutters in one operation.

Turn a steel disc of the form of an ordinary mill cutter, as shown at *l p*, fig. 11, plate VIII. To finish it, giving the same curvature to the two sides, take a piece of steel, C, and shape the corner *r* to exactly correspond with the side of the point or ogive of a tooth, bevelling it so as to give a cutting edge at the upper surface; then harden and smooth it with care. Having fixed it in position in the tool that carries the arbor *a* and the roughed-out disc (whether this be the turns, wheel or pinion-cutting engine, or a special device) in the required position, one side of the disc may be finished. The arbor *a* is then reversed and the other side finished in the same manner, so that both sides have the same curvature in opposite directions.

Of course the tool C may be advanced against *l p*, either sideways from *r* towards *l*, or radially in the direction *l p*, as is most convenient. Or the tool might remain fixed and the disc advance against it radially or laterally.

The transverse slide in a mandril is usually provided with a stop; it would then be very easy to form one side of the disc in such a tool, afterwards reversing the arbor and forming the other side (**477**).

If a very good cutting edge is desired, the sides should be smoothed (**472**) and, when the disc is completed, it may be divided into pieces similar to B, fig. 8, each of which will serve as a cutter. It will be noticed that the acting edge is not undercut behind; it is thus necessary to slope the cutter a little as shown at B, as otherwise the rim will choke in the spaces of the wheel, straining it without cutting.

469. Composite cutter formed of a succession of single cutters.—By mounting a series of identical single cutters round the circumference of a disc, a circular cutter can be formed in the manner indicated in fig. 13, plate VIII. The upper portion represents the arrangement of the pieces

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while they are being turned, and the lower portion shows their positions when the cutter is ready to be used.

M. A. Croutte, to whom we are indebted for several of the details here given, was much surprised that this form of cutter is not better known, since it possesses certain special advantages: we will summarize his remarks on the subject.

The separate cutters *b*, *g*, &c., fig. 13, are not undercut from the acting edge backward; they are merely reversed, so that this acting edge is towards the front—in other words, it lies along the radius. These separate pieces possess a special advantage in that they can be used until the steel is quite worn out by the setting: in this respect differing from the undercut cutters, for they are not altered either in form or thickness by setting.

As a set-off against this important advantage, they are characterized by the inconvenience of requiring that the two sides of the blade be exactly in a plane at right angles to the axis, and that the slide carrying the cutter-arbor shall move in a direction parallel to this plane. And even when this double condition is satisfied, there will be friction of the two sides above the dotted line *i j*, fig. 8, plate VIII., against the sides of the teeth; and if the above-named conditions are not satisfied, the cutter, being presented edgeways, will be choked with brass, and the results will be unsatisfactory.

470. In order to ascertain whether such a fault exists, it is only necessary to notice whether the cutter becomes brass-coloured on one side towards the point, and on the other more inwards, and the sides of the teeth exhibit striæ or scores in opposite directions, as indicated at E, between the figures 5 and 6, plate VII. The white strip, 1, 1, corresponds to the bottom of a space between two teeth; 2, 2 and 3, 3, the two sides of this space spread out like an open book.

By examining the marks with care, and noting the direction in which they are inclined, it will be possible to ascertain both whether the separate cutters are out of place,

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and in which direction the arbor should be moved in order to correct any error.

We must, then, repeat that all the cutters must satisfy this condition, because if only one is wrong it will produce the scores here referred to.

The necessity of these precautions in the use of such a composite cutter, and the fact that the friction of the portion above the line *i j*, fig. 8, plate VIII., renders it difficult to obtain a polished cut (which is essential for such delicate depths as those of watches), have doubtless prevented its use becoming general. For work that is somewhat larger or rough, it will be found to give satisfactory results and will last longer than a single cutter. A lubricant, such as lard o oil, should be applied to it.

471. Composite cutters with the cutting edges undercut.—An old Paris clockmaker, Brisson, used a cutter of the form F, fig. 11, plate VIII., for the teeth of his wheels. He undercut the two sides of the blades by means of a small special tool. Strictly speaking, the operation can be performed by hand.

In order to ensure that the curves that form the ogives of teeth are alike on the two sides of a cutter, he made a series of templates or standards of the form C, fig. 13, plate VIII., in which were two holes C and *c* of equal diameter. The upper one, which might be funnel-shaped so as to give a cutting edge, was half cut away, and, after being hardened and set, could be used to give a final stroke to the circumference of two discs of equal diameter. These two discs (or one cut through a diameter would suffice) having been brought by a file to the form H, and joined as shown at *r s*, can be mounted excentrically so as to present a cutting edge to the roughed-out cutter A; the two sides can thus be made even. The disc may then be finished by cutting away the metal so as to give the form shown at F, fig. 11, plate VIII.

By the aid of the standards he could easily reproduce the same forms of teeth when required.

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Fig. 11, plate VIII., comprises, at J, a cutter for the teeth of watch-wheels of the form employed successfully by M. A. Philippe. The figure will explain itself.

We have known a Geneva wheel-cutter who employed these composite cutters with advantage in making duplex wheels. The principal difficulty he experienced arose from the distortion of the metal in hardening, because the acting portion naturally lengthened a little. This form of composite cutter certainly demands careful workmanship, but, if the construction, hardening and polishing, are good, it will produce fine work and will last a long time.

472. General observations on cutting the teeth of brass wheels with a single or compound cutter.—High-class English watches, the movements for which are made at Prescot, in Lancashire, have the wheel teeth made by a composite cutter after the wheels are riveted to their pinions. We have remarked that these watches make less noise when running down than those in which the teeth have been formed with a mill or continuous-action cutter.

Success in forming teeth with cutters depends mainly on the securing of a good form as regards the cutting edge and on its being maintained in good condition (**296**); on the steadiness of the entire machine, so as to avoid vibration; on the weight of the wheel, and on the velocity of the cutter being sufficient. A cutter ought never to assume a brassy colour except when it requires setting; if it does so, and this is not the case, it proves that the metal is being strained or scraped with friction. The velocity must be very considerable; greater with a single cutter than with one that is composite. The velocity is limited by that at which the heat generated would cause the oil to evaporate, soften the cutter, distort, and sometimes even displace, the wheel operated on. The engagement of the cutter with the metal must be very slight, and should never be increased suddenly.

Attempts have been made to enclose the arbor bearings in horn, but it is liable to be distorted by the heat.

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Before dividing the disc into cutters it is essential that the two edges be carefully smoothed, and this without their being distorted. This can easily be done in an old depthing tool, using an arrangement like that shown in fig. 18, plate VI. (**377**). The lap must be of hard wood, and its right-hand corner rounded off so as to resemble the side of a tooth; it is set to engage with one side of the cutter. We say the right-hand corner, because a lateral pressure can then be applied. It is important that the surface as left by the graver be clean cut, because, if the smoothing is too much prolonged, it will deform the cutter. Some of the remarks in paragraph **482**, are applicable here. (See also the *Treatise on Modern Horology*, pp. 326, 440.)

473. In some factories it is usual to use discs about 2½ inches in diameter, for cutting the teeth of brass wheels in timepieces. The single cutters are arranged round the circumference as follows:—One forms a space between two teeth; the one immediately preceding forms the right-hand side of the ogive, and that which follows forms the left-hand side. By adopting such an arrangement of separate cutters, if their side that lies against the disc is slightly inclined backwards it is no longer necessary to bevel off the cutting edge.

MILL-CUTTERS FOR STEEL.

Pinions, keyless wheels, &c.

474. The cutters that last for the longest period when used for cutting steel are those formed like a file; but a watchmaker is not always in a position to make them himself; we will therefore here only speak of those he can make, the description of the first few being taken from a work by M. A. Philippe, of Geneva, *Les montres sans clefs* (keyless watches).

475. Cutter for forming the inclined teeth of winding pinions, &c.—Fig. 20, plate VIII., shows at s a section

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along the axis of such a cutter, and at P a side view. When it is believed to be of the required form, rest a piece of lead on the T-rest of the lathe and press it against the rotating disc. The impression made in the lead will afford a means of ascertaining both whether the form is correct, and whether the surfaces are smooth enough. This last point is important.

The cutting edges are formed by merely making a number of notches round the circumference with a tool for cutting ratchet teeth. Then advance this ratchet cutter so that it may engage with the convex edge of the cutter operated upon, and against the back of the teeth of this cutter; the ratchet cutter is then in a position to form a second face *e i*, by which the teeth of the cutter are undercut at the back, but in such a manner that a small flat surface *o a* is left in order to retain the form. When a cutter made in this way will no longer bite, it may be set by passing a hard slip of whetstone over the faces of the teeth.

The ratchet cutter employed for making this cutter should never be pressed against it heavily, and should be withdrawn during the upward motion of the bow.

476. Cutter for ordnary wheel-teeth.—We will now pass to the consideration of the cutters for forming teeth of the usual shape, of intermediate steel wheels, set-hands wheels, pinions, &c. They may be made as follows:—

The rim is indented with small fine ratchet teeth, *b d*, fig. 21, plate VIII. Any burr produced on the sides is then carefully removed, and the cutter is placed in the wheel-cutting engine, and notches *c*, c^{1}, c^{11}, c^{111}, &c., are formed on either side with a flat square-edged cutter of such a thickness that the circumference is about equally divided into hollows and prominences. It is important to note that the right side of the teeth must be but slightly roughed, not more than is required in order to raise a slight burr, all that is necessary to form the cutting edge of this portion of the isc. In roughing these sides, at least one out of every two

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of the small ratchet teeth on the circumference should be left untouched, so as to ensure the required thickness being maintained.

The cutter shown in section and elevation at S and P, fig. 20, plate VIII., might be cut on the side *n* in the manner here explained, and the convex portion *k* might be indented with a fine ratchet-toothed cutter carried in the hinged cutter-frame of the wheel-cutting engine. The degree of penetration may be determined by fixing an ivory disc against the cutter and concentric with it, the two differing in diameter by the depth the cuts are to be made. The teeth will be rather too square towards the circumference, but their form can be carefully corrected by hand.

It is obvious that the very greatest caution is necessary in hardening cutters.

477. Rose-cutters or forming pinion cutters.—As the edges of pinion cutters are rounded, they can be made in the manner suggested by Thevenin. Supporting the roughed-out cutter in the cutter frame of a wheel-cutting engine, he fitted in the axis of the division-plate a kind of rose-cutter, N, fig. 23, plate VIII. Its extremity *n*, instead of being flat, is hollowed out as indicated by the dotted line, and, by presenting the cutting edge thus obtained endwise to the grooved edge of the cutter, the correct form can be given to it. With a mushroom-headed piece of steel and oilstone dust, the cutting edge of the rose-cutter can be made more or less acute by modifying the angle of this steel lap.

478. Other forms of pinion cutter.—When a cutter is merely required for a special piece of work and not for continuous use, it will often be sufficient to make it as shown at A, fig. 22, plate VIII.; this is made by grooving the disc (*c*), or by forming its edges as at *d*, after which a series of teeth are cut on the periphery with a revolving cutter, taking care to leave no more burr on one side than on the other. Then pass a smooth worn file (or a worn flat cutter driven by a

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bow) over the faces of the teeth, applying oil at the same time, so as to produce a slight burr on the edges; if the file is not allowed to bite too much and is well managed, these minute ridges will be uniform. After hardening, the cutter is ready for use.

If the faces were smoothed without subsequently applying the file, the cutter would not bite; for its action depends on the slight projection of metal that corresponds to the file-cuts. The cutter is nothing more than a circular file with two cuts per tooth. If the corners are turned over evenly by means of a very hard burnisher the same effect will be produced; but this operation is delicate as the amount of metal turned over must be the same in every case.

When a cutter does not bite, it must be softened and restored to its initial condition.

479. Or the following method may be adopted when it is required to make a cutter for a special purpose.

Proceed at first in the manner just described, but the periphery is divided into a greater number of teeth with a flat cutter, and to a rather greater depth, as at E, fig. 22, plate VIII. Bend backward each tooth to a distance equal to about half a space by any convenient method; for example, by a lever resting at the bottom of each space and pressing against the corner of the tooth, &c. Before bending the first tooth introduce a piece of brass into the space behind it, of a thickness equal to about half this space so as to avoid bending too far; for succeeding teeth the thickness must be about equal to a space; thus E will become E^1. An inspection of fig. 22, plate VIII., will suffice to make the operation evident; it amounts to bending back a series of separate cutters. The disc is then hardened, and the faces of the teeth are smoothed when they do not cut well; or merely smooth those that are the first to become dull.

It is important to employ soft steel that has previously been well annealed.

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480. Cutter for making square spaces.—The teeth of such a cutter can be easily formed with a file as shown at L, fig. 4, plate XII., the edge of the cutter, *f*, being passed backwards and forwards in the direction of the arrows, applying considerable pressure and at the same time slowly rolling *f* round. Or the cutter may be set up on a short arbor between the centres of the turns; then pass the file backwards and forwards across the edge until the cuts are formed, slowly advancing the file in the meanwhile, so as to form the cuts round the circumference without once raising the file. The cutter must then of course be hardened.

481. Forming cutters with a milling tool.—The roughing of a round-edged, or even of a square cutter, can also be effected with the aid of a milling or "nurling" tool, proceeding in the same manner as when milling the heads of screws, &c. The tool must be in good condition, well provided with oil, and applied with considerable pressure against very soft steel.

If necessary the workman can make the mill for himself; it is shown at M, fig. 4, plate XII. F shows the method of applying it to the cutter, and by partly turning the mill (of course carried in a strong holder) round its point of contact with the cutter, as indicated by the dotted lines, the rim of F will be evenly roughed all round.

With good steel fairly satisfactory results are obtained in this manner, but it is needless to observe that such cutters never bite as well as those made in the usual manner.

482. General observations.—When cutters are used with steel they must be driven at a less velocity than when cutting brass, and, as M. A. Philippe has observed, it is best to make the cutters for steel of small diameter (about half an inch). They are more easily made and are less distorted in the hardening. The velocity should diminish as the diameter increases; for too great a velocity, especially when the diameter is great, will dull the cutter and soften it owing to the heat produced.

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Cutters mu t be turned very true : it is advisable to give them a last stroke with the graver after they are fitted to the cutter-arbor that will subsequently carry them.

When operating on steel it is best that the cutter frame of the wheel-cutting engine be advanced by a screw so as to give it a slow and easy motion ; the results obtained are more satisfactory than when it is advanced by hand or with a lever.

The following practice is not uncommon in factories when it is desired to reproduce the exact form of a cutter. A notch is made with the cutter in the edge of a piece of steel, x, fig. 2, plate VII., or a series of notches o, o^1, &c., can be made by several cutters in the circumference of a disc z (same figure). After being hardened and sharpened at the cutting edge, this disc is fixed at the centre of the division-plate of a wheel-cutting engine, and can then be used to complete the grooving of any cutter that is set in position on the cutter-arbor before hardening. The positions opposite to which the notches were cut should be marked on the chuck, so that they may always be set square to the cutter.

483. Besides the forms of cutter above described for operating on steel, we may mention that circular cutters may be used in which all the notches round the circumference have been polished, thus removing the burr, and preventing them from acting in the manner of a file. But while, with the former kind, a somewhat rapid rotation is necessary (although not so rapid as when cutting brass), with this latter class the movement must be comparatively slow, and produced by means of a hand-wheel ; otherwise they will not cut, since the action depends rather on the application of pressure, and resembles that of a slide-rest cutter. The distance apart and width of the teeth of the cutter, as well as their inclination, are of importance ; if too far apart they occasion a waste of time ; if too large the machine will act in a jerky manner, and when too narrow, an excessive pressure

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will be needed in order to make the cutter bite the steel, which, it is to be observed, must always be thoroughly annealed. The edge must be well supplied with oil or soapy water when in action.

It is generally found best to advance the cutter against the edge of the steel rather than across it.

TOOL FOR MAKING CUTTERS.

484. The instruments usually employed for making cutters for the teeth of wheels and pinions are complicated and expensive, but the author has designed one for his own use that is comparatively simple, and can be made by any watchmaker. When the reader has grasped the principle on which it acts he will be able, without difficulty, to modify it so as to suit his requirements.

The frame B B *b*, figs. 1 and 2, plate XIV., consists of the body of the tool, B B, and a bar *b b*, which is attached to it by screws. Between the two the division-plate P rotates on an axis E R. The end E of this axis is formed as a chuck to receive the cutter *f*, which is clamped by a screw *t*.

The support S *s* J is held with friction in the lower part of this frame, to carry the cutter-holder A L M. This cutter-holder is hinged at *n*, so that it can receive a double motion, revolving about a horizontal axis J, and about an inclined axis *n*.

The portion A L of the cutter-holder carries a perforated arbor *a c*, with a ferrule *c* that receives the tail of the small rose-cutter, which will presently be described.

The end M rests against a guide G, held by a vane *o z*, which is pivoted on a pillar *z*, and can be clamped in either of the directions *z y*, *z x* by one of the screws *o*, *o*.

485. We will now consider the mode of action of the machine. Having set the little arbor *c a* in rotation, rest the end M of the arm against the guide, and gradually advance the rose-cutter towards *f*; the edge of *d* will form

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the first notch in the grooved rim of the cutter, and then will be raised from contact with it, owing to the influence of the guide G. After moving the tool-holder back to its initial position, advance the wheel P by a tooth, repeat the operation, and so on.

86. If the cutter *f* has to be notched on both sides, it must be reversed on the chuck; turn the guide so as to point in the direction *z x*, corresponding exactly to *z y*; then having set the cutter-holder in the line *x h*, re-commence operations. The two grooves of the cutter will then necessarily be of similar form.

Teeth can be cut on the rim of *f* by using a cutter of the form F, fig. 4, and holding M against a straight vertical guide.

With a given divided wheel, P, the teeth can be brought nearer together by reducing the diameter of the cutter, and *vice versâ*. It is well to have some change wheels, but a better plan is to advance the division-plate by the aid of a tangent screw.

To make the several accessories.

487. *Form of the rose or star-cutter.*—The rose-cutter is formed of a mushroom-headed piece of steel. Such a conical cutter is shown at C and R, fig. 5, and at F, fig. 4, plate XIV. F and C are cut in the same way that conical cutters are always made, and R is a small triangular prism that only cuts by its three corners, *a*, *a*, *a*. As it is necessarily very small when employed in making the cutters for watch pinions, it must, in such a case, be supported at the neck by a little fork. Moreover, it must be brought gradually against the steel to be operated upon, so as only to engage a very little at a time. With a view to this, it is advisable that the cutter-holder be advanced by a screw.

The star-cutter, shown at E, fig. 3, is at times substituted for the rose-cutter. It cuts with the corners *e*, *e*, &c., whether

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it be going to the right or left indifferently. Or a triangular cutter like T, fig. 3, can be used in its place ; but its angles are fewer and less acute, so that they become dull more rapidly.

A few trials will be needed in order to determine the most convenient rate of movement of the several parts ; and the edge of the cutter *f* must always be liberally supplied with oil. A little can may be so arranged as to allow oil to fall drop by drop on to the cutter *d* (fig. 2).

488. *To make the guide.*—Having mounted a plate, G, on the vane *o z*, trace out the approximate form of the cutter with the point of M ; then cut off the superfluous metal, leaving a slight margin. This excess is necessary because the curvature of the guide is not the same as that of the cutter, for the indentations as they spread out from the centre (*t*) become gradually deeper. The guide should be tested from time to time by operating on a blank brass disc fixed in place of the cutter *f*, and the guide must be modified as experience shows to be requisite. Its edge must be saddle-shaped so that the middle may correspond exactly with the two dotted lines *z x*, *z y* (fig. 2).

The position of the disc on the chuck *t* must be brought to correspond with the guide by carefully turned washers placed behind it.

489. *Driving attachment.*—Fig. 4, plate XIV., shows one system that may be adopted for connecting the ferrule C with a driving-wheel. All that is required is that the instrument be set in such a position that this ferrule is placed as indicated in the figure with reference to the distributor.

490. *Cutters of uneven thickness at the circumference.*—It is well-known that the edges of the cutters of rounding-up tools (**492**) are made to taper off round the periphery. In order to indent such a cutter, the guide must be mounted on a slide, so that it may be gradually displaced while the operation is in progress, by an amount previously determined upon.

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The desired result can be obtained with sufficient accuracy by moving the guide backwards by successive stages with a screw. The end *k* of the arm M, fig. 2, is slightly tapered, so that a gradual depression of M occurs, and each cut is deeper than that which preceded it.

491. *Modification in the construction.*—This instrument may be modified as follows : The disc to be operated upon is fitted to the chuck of the division-plate D, fig. 6, plate XIV., which is vertical, and the entire system is capable of a movement of rotation round the axis of the base P. Having set the disc in the plane *a b*, as shown in the figure, clamp P ; then, by traversing the cutter-holder, the teeth on the side of the cutter towards *a b* are made. This cutter-frame having now been removed, the base P is turned until the cutter is in the plane *c n*, such that it is equally inclined on the opposite side of the axis of the cutter frame ; the teeth on that side may then be made, the star-cutter being rotated in an opposite direction.

It is unnecessary to prolong our explanations of the instrument, as the details already given will suffice for any intelligent workman.

TOOLS FOR CORRECTING THE FORM OF TEETH.

492. Rounding-up tools.—On the Continent it is the practice, in making watch-wheels, to first notch the circumference by means of a flat circular cutter in a wheel-cutting engine, thus forming a number of square teeth. They are subsequently rounded off to the usual form, after the wheels are riveted to their pinions, in a special tool.

The apparatus employed for this purpose is termed a rounding-up tool, and its principal feature is a mill-cutter F, fig. 16, plate VIII., the portion *a b* of whose circumference is cut away and replaced by a guide *g f* made of steel spring, and so fixed as to coincide with the edge of the cutter at *f*, and incline at *g* in order to compel the cutter to pass, at each

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rotation, into consecutive spaces of the wheel. Two screws are provided, the one *f* for setting the guide opposite the edge of the cutter, and *g* for placing the free end of the guide opposite to a space.

This tool acts with great rapidity, a fact which has led to

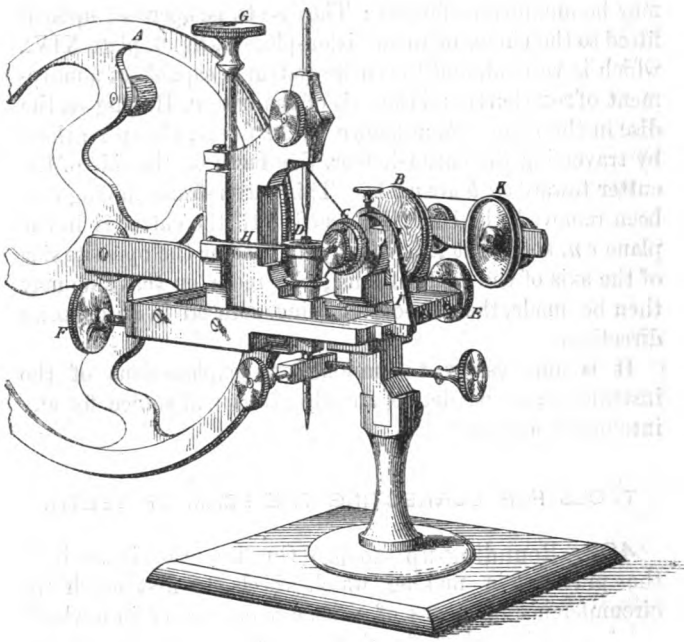

FIG. 18.

its being very extensively used in the factories of France and Switzerland, although the ordinary system of wheel-cutting (**454**) is preferred in England and on the Continent for all the better class of work. For it should be noted that the rounding-up tool does not correct any errors that are due to bad dividing; for example, if a wheel is found to

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have some of its teeth larger than others, the tool cannot be relied on to correct them; on the other hand, if a wheel is exactly divided it is improbable that the employment of this tool will occasion irregularity.

The instrument we are discussing has, however, not been much used by watch-jobbers until quite recently, although they are frequently called upon to touch up the teeth of wheels, or to slightly reduce the diameters of their pitch circles, operations which cannot be done by hand with much chance of success. The limited use to which rounding-up tools have been put is owing, in great part, to their high price, but cheaper tools on this principle are now coming into use.

493. One of these is shown in the annexed figure 18. The wheel to be operated upon is held against a small table at D between two vertical runners with guard-pivot centres, and a cutter of the form shown at fig. 16, plate VIII., is fixed at C to a suitable chuck of a small lathe-head B; this is caused to revolve by the hand-wheel A, a supplementary pulley K taking all strain off the axis. The three milled-headed nuts seen at E, F, and G are for adjusting the instrument; E for moving the lathe-head, so that the cutter is in the same plane as the axis of the runners, a position which is determined by the pointer I; F for advancing the wheel against this cutter; and G for setting the plane of the wheel to pass through the axis of the lathe-head as indicated by the index H. The instrument is accompanied by a number of cutters to suit the various sizes of teeth ordinarily met with, as well as of tables to support wheels of different dimensions.

494. Ingold fraise or cutter. Rounding-up cones.—Either the cutters devised by M. Ingold, or the rounding-up cones of M. Berlioz, may be used for correcting the form of wheel-teeth.

The Ingold fraise is a small steel cylinder perforated through the axis so as to be mounted on an arbor, and having a number of longitudinal notches on its circumference

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which make it resemble a pinion, the points of whose leaves have been ground off. The spaces of the fraise are of the exact form required to be given to the teeth of the wheel, and their surfaces are covered with fine file cuts so as to enable them to remove metal from the wheel operated on.

Having mounted the arbor that carries it between two centres of a depthing tool (made specially strong for the purpose), the wheel is supported by its axis between the second pair of centres (with guard-pivot points). If now the fraise be advanced by the screw until its teeth engage with those of the wheel, and either be caused to rotate, it will drive the other, and the fraise will thus shape the teeth to a pre-determined form, the faces of each notch acting the part of a minute file introduced between the teeth.

It will be observed that such an instrument is preferable to the ordinary rounding-up tool, in that it may be relied upon to bring all the teeth to the same shape, but, on the other hand, the latter tool has an advantage in being available for slightly reducing the diameter of a wheel when a depth is found to be too strong.

495. An objection has been urged against the Ingold fraises on the ground of expense, as each dimension of tooth evidently requires a cylinder specially adapted to it. This fact has led to the introduction of "rounding-up cones," the invention of M. Berlioz, which act on precisely the same principle, but are conical instead of cylindrical, so that each fraise evidently takes the place of a number of Ingold fraises, the total number being proportionately reduced. But great dexterity is required in their use, so that they cannot be successfully employed until after numerous trials.

496. Exact rounding-up tool.—The author has devised an instrument for giving to the teeth of wheels the exact form determined upon by theory, but as it is of too elaborate a nature to come into general use, we shall not do more than

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here refer to it.* It is rather of a nature to be used for scientific work, but might be found of considerable value for accurately forming the blades of cutters that are used in grooving the circular cutters employed for cutting the teeth of wheels.

497. To round up teeth by hand.—We have seen a country watchmaker proceed somewhat as follows: his method was only effective, however, for ensuring the verticality of the file, and did not maintain it straight, nor could the curvature of all the teeth be relied upon to be the same; these two conditions are satisfied by the system here explained.

Formerly watchmakers possessed very considerable skill in this kind of work, as the teeth were always formed by hand; but at the present day, for want of practice, there is not one to be found in a hundred competent to round up a wheel properly by hand alone. Recourse may be had to the following expedient in an emergency: it necessitates the construction of a small special tool, but this is so simple that it can be made in a few hours by an apprentice.

498. Take a bar of metal or hard wood, made smooth on its faces and square at the corners (R, fig. 5, plate XI.), and adapt to it a slide *c c*, through the centre of which a slot is cut to receive a clamping screw; it slides between the four pins indicated in the figure. An arbor *a* is supported by *c c*, parallel to R, having a plate at its end on which a wheel to be operated on can be fixed by three screws and a loose plate. It is centred by the circumference before clamping these screws, rotating *a* with a bow, and it may be well to place a piece of tissue paper under and over the wheel in order to avoid scratches. V is a tongue that can be introduced into the space between two teeth in order to prevent the wheel from moving.

* For description see *Revue Chronométrique*, Vol. II. (1859), p. 170.

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Two arms *p*, *p*, screwed to the bar R R, support the handle of the rounding-up file *l*, which consists of a large cylinder T, having, at either end, long thick pivots, or rather rods, *t*, *t*, that slide in the arms *p*, *p*. The cylinder T must be exactly parallel to the arbor *a*, and the longer it is the better. The file-holder, *s*, also shown detached at Y, fig. 6, is merely driven on to the rod *t*. The distance between the centre of the axis *t* and the face of the file (*b* b^1, fig. 6) is equal to the radius of the circle that embraces the external curves of two or more teeth, as will be presently explained.

The several parts being arranged as shown in fig. 5, and the bar clamped in a vice at E, it will be obvious that, if the wheel is held in two fingers of the left hand so as to prevent it from being displaced, while the rod T is moved up and down, at the same time rotating it with the right hand, the curves of two teeth will be adjusted to correspond with the arc *o o o* (Z, fig. 6), and, by transferring the tongue V to the next succeeding space, the curve *i i i* can be struck.

499. *Observations.*—As we have shown in the *Treatise on Modern Horology* (pages 615—16), the curvature of the point of a tooth coincides very closely with a circular arc described from a certain definite centre, and comprising either two or three teeth. In order to realize these conditions in practice, the slide *c c* is so adjusted that the axis of T passes just within the circle that passes through *o*, *o*, *o*, &c. (Z, fig. 6), at which the points of the teeth commence; by making trials with two or three file-holders that differ in regard to the distance *b* b^1 (Y, fig. 6), it will be easy to select the most suitable for producing the required curve. After operating on all the teeth in succession, advance the wheel by means of the screw D, and again work round the circumference, and so on.

The progress of the work should be frequently examined with the glass.

It is possible to dispense with the tongue V, and to merely

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steady the wheel by hand; the work is thus done more rapidly, but must be examined with very great care.

We would insist that the lengths of the two axes are an element of success. In operating on watch-wheels T should not be less than six inches long.

By suppressing the tongue the motion of the two axes may be co-ordinated so as to form any theoretical curve; this is the case in the exact rounding-up tool already referred to, but it of course renders the instrument more complicated.

500. To ease a train of wheels.—In very many of the cheaper watches and timepieces now met with in commerce the teeth are rough and badly cut, and the pinions but little polished, so that watchmakers are constantly complaining of the difficulty of securing even a moderately good depth. In such cases they have a simple method to adopt in addition to those already referred to, namely, to polish the teeth with a piece of charcoal.

A piece of smooth even charcoal with regular fibre is moistened with oil or water, and passed across the teeth individually; first with the fibres lying in the direction of motion, and afterwards with them at right angles to that direction.

If the charcoal is carefully selected and lightly applied for a sufficient length of time and no more, the ogives will be found to be nicely smoothed, and the depth will run far more easily than it did previously.

It is dangerous to use quick-cutting charcoal as it is apt to deform the teeth.

Smoothing with a brush charged with charcoal powder cannot be regarded as anything more than cleaning; if the action is too much prolonged the form of the teeth will be spoilt.

TO TEST THE ACCURACY OF CERTAIN TOOLS.

501. Drilling tool.—First centre the runner in the turns, and ascertain that it is straight, cylindrical, and

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exactly centred; then fit a ring to it so as to slide with friction to (temporarily) limit the descent of this runner in the vertical stock of the tool.

After placing it in position, adapt to its lower end a collar provided with a long index of soft brass, which is bent so as almost to touch the plate at its circumference. Rotate the runner and it will be shown to be perpendicular to the plate if the point of the index remains at the same distance from the plate.

As a confirmatory test the runner may be drawn up in the stock, and the trial repeated after bending the index nearly to touch the plate.

502. Uprighting tool.—If the two stocks or tubes that receive the runners are exactly in line, a runner should move easily through the two at once.

Setting the points in contact in various positions in a vertical line, observe whether they coincide, both when at rest and when rotated together or independently.

First ascertain that the table is at right angles to the axis in the manner already explained for the drilling tool, making the necessary tests with the two runners independently. Then support between their points a short arbor carrying a soft brass index. The position of the lower runner being maintained constant by means of a collar as above explained, rotate the upper one by hand; its friction will carry the arbor and index round, the point of this latter being set close to the plate. Repeat the operation by raising the pair of runners and bending the index down to the same amount.

If in these various positions the point remains at the same distance from the table, it affords evidence that the tool is accurate.

An uprighting tool consists of two parts: the table carrying the lower stock, and the bridge that forms the upper stock. The base of this latter is a ring turned flat and co-axial with the stock, and is fitted accurately into a square groove surrounding the table, where it is fixed by screws.

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Any watchmaker understanding this mode of construction will easily perceive when he has tested the tool in the manner above indicated, both what are its faults and how far he can correct them. (See articles **391, 412—3.**)

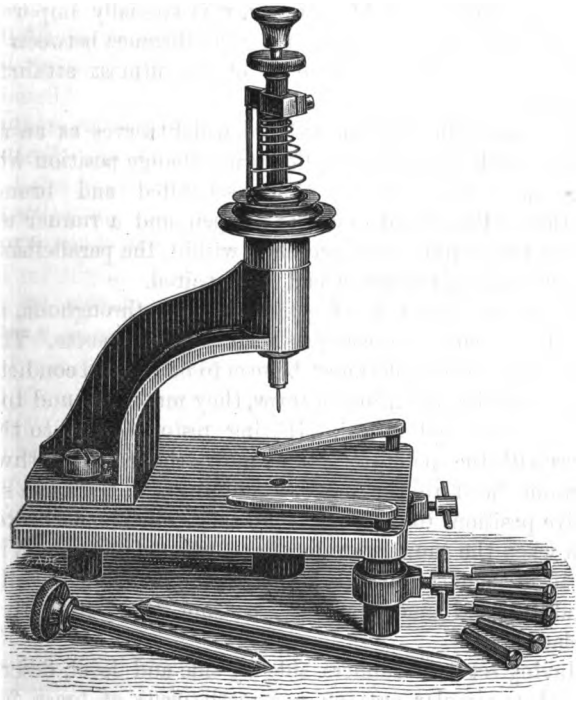

Fig. 19.

503. The English uprighting and drilling tools, and some of foreign construction, are combined on the same stand, and a good arrangement, made by Boley, is shown in fig. 19. It will be seen that the drill can be set in motion by a hand or foot-wheel; the table is fixed in a vice and

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provided with two dogs for clamping the object. The drilling spindle is perforated throughout its length so that the drill can be held by an American split chuck (**283**).

504. Depthing tool.—As the goodness of a depth depends essentially on the overlapping of the teeth being the exact amount required by theory, it is specially important that the tool used for determining the distance between the centres of the mobiles should be of the utmost attainable accuracy.

First ascertain that the spindle which serves as an axis for the two halves of the tool does not change position when they have been several times separated and brought together. For, if this were to happen, and a runner were uneven or the hinge not smoothed within, the parallelism of the two pairs of runners would be impaired.

The runners must be of equal thickness throughout, and should pass with ease from one head to that opposite. Their points and centre-holes must be seen to be in good condition, and, on placing them in the turns, they must be found to be both true and cylindrical. Having restored them to their places with the points together, move the pair lengthwise from one head to the other, examining the points in successive positions to ascertain that they coincide accurately, both when the runners are loose and when clamped. When the adjustment has been carelessly done the runners will be found to bend under pressure, causing the points to be displaced.

Having set two runners side by side and level, describe with them circular arcs on a smooth piece of brass from centres previously marked, first with the points just projecting from the heads and then projecting more and more. These tests may be made both within and without the tool; so that there will be four sets of tests in all.

It is very important in making the last-named trials, that the tool be maintained at right angles to the plate on which the circular arcs are traced; this condition can easily be

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satisfied by a special device, or by merely causing the compass to slide along a set-square. It may be added that the series of arcs should be drawn end to end, in order that it may be easier to observe their agreement or difference when examining with the glass.

505. When this series of tests has been gone through, and the points have been examined so as to make sure that there is no burr which bends over while tracing the arcs, it is possible to determine the value of the tool; we know whether it is perfect or not, and what corrections are required. As a rule there are two points mainly at fault; the holes in the heads are not exact continuations the one of the other, so that they need to be broached out afresh (**709**), and new runners have to be made. A careful and intelligent workman who is provided with suitable tools will be able, from the information given in this work, to correct, or at least improve, a defective depthing tool; but, as a rule, it will be better done by the maker.

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PART V.

ON REPAIRING AND EXAMINING WATCHES.

METHOD.

506. Expedition and certainty in watchmaking and repairing are primarily secured by proceeding on a definite system both in the preliminary examination of the watch and in details of construction or repairing.

The best watchmakers, and practical men generally, take their work in a certain order, from which any departure is exceptional. By this means they avoid the necessity of doing work twice over and of frequently taking up the same piece ; a circumstance that often occurs with young watchmakers, owing to forgetfulness or to a want of sequence in their ideas.

They should from the first exercise themselves in working methodically on a definite system.

It must, however, be understood that no method can be inflexible, nor can it be equally advantageous for different individuals, because men differ in regard to manual dexterity, goodness of eyesight and of memory, power of associating their ideas, &c. A system that is suitable to a person of unexcitable temperament will have to be modified by one who is oppositely disposed. Everyone will be able to decide for himself as to the best system to adopt and the order in which to take his daily work.

These preliminary observations appear necessary because

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the method explained below of examining a Geneva watch has been regarded by some as too long and minute. We would urge any young watchmaker that hears such ideas advanced to assure himself that it is a mistake, because the system here explained is only put forward subject to the modifications that experience suggests; and it is to be observed that many of the operations given can be performed more rapidly than they are described.

When a watchmaker experiences a great loss of time, does it not usually arise from the fact that he is obliged to take a watch to pieces, or nearly so, after its repairing and examination were thought to have been completed; or when a watch that has been repaired is brought back to be examined before the ordinary period of cleaning has elapsed?

Let him add together the numerous hours spent in this kind of thankless work, let him sum up the worries experienced, and the discredit, &c., to which he has been subjected, and he will see that systematic work would have saved him both loss of money and loss of credit.

EXTERNAL EXAMINATION OF THE WATCH.

507. In the following paragraphs, when the manner in which a given fault is not indicated at once, it should be sought in the index of this volume, either under the name of the operation or under that of the object to which it relates. The reader will see for himself which passages refer exclusively to the English and which to the Geneva watch.

508. Case, glass, dial, dome.—Glance at the case in order to ascertain that it has not received a blow or been subjected to pressure; that the joints and fly springs work well; and that the hands in rotating touch neither the glass nor dial. By laying the nail on the surface of the glass, it will be easy to see whether there is sufficient freedom between the socket of the hand and the glass. In case of doubt, place a small piece of paper on the hand, close the bezel and

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tap the glass with the finger while the watch is in an inclined position. If free, the paper will be displaced.

The set-hands square should be rounded at the end and a trifle below the level of the dome in order to avoid the possibility of contact in case of any accidental bending of the back of the watch, and the dome must not press on the balance-cock wing or the central dust cap (if present). The above remark also applies to the winding square of a fusee watch.

There must be sufficient freedom between the going-barrel teeth and the banking-pin of the balance on the one hand, and the internal rim of the case, the fly-springs, and the joints on the other. Otherwise there is danger of contacts when the case is closed which occasion irregularity and stoppage often difficult to detect.

509. The dome must be at a sufficient distance from all parts of the movement, more especially the balance-cock. If there is any occasion for doubt on this point put a thin layer of rouge on the parts that are most prominent. Close the case and, holding it in one hand to the ear, apply a pressure at all parts of the back with a finger of the other hand, listening attentively in order to ascertain whether the vibrations are interfered with. If the interval is insufficient, a trace of rouge will be found on the inside of the dome. In such a case, if the dome cannot be raised nor hollowed slightly in the mandril (when formed of metal), lower as far as possible the index work and the balance-cock wing and fix in the plate, close to the balance, one or two screws with mushroom heads that will serve to raise the dome.

Ascertain that the hands stand sufficiently far apart; that the hour hand does not rub against the hole in the dial; and that the minute hand does not come nearer to the dial in one place than in another, a fault which may arise either from the dial not being flat or from the centre-wheel being badly planted (**518**).

Remove the movement from its case, after making sure

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that it is held steadily by the locking screws; take off the hands, and see that the hour wheel has the right amount of play; this freedom may be diminished if required by laying on the wheel small discs of tinsel cut out with a punch. If the dial presses against any part of the movement, or is not flat or comes so near to any of the pivot holes as to draw off the oil, it must be ground away until a sufficient amount of freedom is obtained (**674**).

TO EXAMINE A GENEVA MOVEMENT.

510. Although the following remarks refer in the main to foreign watches with a Lepine movement, very many are also applicable to the English watch; further observations specially bearing on it will be found in articles **534—7.**

511. The motion work and hands.—Rotate the wheels connecting the hour and minute-hands by the aid of a key and a glance will suffice to show whether the several depths, which should be light, are satisfactory. The wheels should not rub against one another, the plate, barrel, or stopwork. The barrel should have been previously examined to ascertain that it is not inclined to one side, as, if it were, an error would probably be made in estimating the degree of freedom.

The set-hands arbor (the square of which should be a trifle smaller than that of the barrel arbor) must turn rather stiffly in the centre pinion, and the cannon-pinion must be held on the arbor sufficiently tight to avoid al chance of its rising and so becoming loose; for this would alter the play of the hands and motion work. If any fault is found in the adjustment correct it at once, so as to avoid doing so after the movement has been cleaned (**614**).

If it has not been already done, slightly round the lower end of cannon-pinion and the steel shield, care being taken to avoid forming a burr on the pinion leaves. These two pieces ought to rest on the ends of the centre pinion pivots,

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and at the same time be some distance removed from the plate and bar respectively.

512. Freedom and endshake.—Observe that there is sufficient clearance between the plate and barrel; the barrel and centre-wheel; the several wheels in succession, both between themselves, their cocks, and sinks; between the balance on the one hand and its cock, the centre-wheel, fourth wheel cock, the balance-spring coils and stud on the other. The fourth wheel is frequently found to pass too near to the jewel forming the lower pivot-hole of the escape-wheel.

The endshake of the wheels may be tested by taking hold of an arm of each with tweezers and lifting it. This may also be done in the case of the escape-wheel, but, when the cock is slight, it will be sufficient to press gently upon it with a pegwood stick, then releasing it, and observing the apparent increase in the length of pivot. At the same time ascertain that the width and height of the passage in the cock is enough to allow the teeth, when carrying oil, to pass with the requisite freedom (**417**).

Holding the watch on a level with the eye, lightly raise the balance with a pegwood point several times, each time allowing it to fall. The variation observed in the space between the collet and cock will indicate the endshake of the balance-staff.

513. Action of the escapement.—The side play of the balance pivots in their holes can, with practice, be easily estimated by touch, or this may be done by the eye, attentively watching the upper pivot through the endstone with a powerful glass, while the watch lies flat, and the lower pivot in the same manner with the watch inverted. If the endstones are not clear enough, although such a case is rare, remove first one endstone and examine the pivot; then replace it and remove the other.

It should be possible to rotate the balance until the banking pin comes against its stop, without causing the escape-

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wheel to recoil at all, or allowing a tooth to catch outside the cylinder behind the small lip. The banking-pin sometimes passes too near to the fourth wheel staff. The U-arms should rest as nearly as possible in the middle of the banking slot of the cylinder; that is to say, they should be as far from the upper as from the under edge of this slot, so that the endshakes may have free play in all positions of the watch.

Ascertain that the balance-spring is flat; that it coils and uncoils regularly without constraint; that it does not touch the centre wheel, the stud, or the inner curb-pin (with its second coil). The rapid examination of the escapement may now be regarded as completed if the watch in hand is merely being cleaned after having previously gone well.

But if engaged on a watch that has not gone well previously, or if examining a new one, the action of the escapement must be thoroughly tested in the manner described for each particular form of escapement in the *Treatise on Modern Horology*.

514. Visible depths.—While the train is in motion through the force of the mainspring or the pressure of a finger against the barrel teeth, examine with a glass all the depths that are visible. That of the escapement, for example, can be easily seen through the jewelled pivot-hole when this is flat, the watch being laid horizontal and a powerful glass used. When the action cannot be seen in this manner with sufficient distinctness, hold the watch up against the light and look through it. Depths that cannot be clearly seen, or about which any doubt exists, must be subsequently verified by touch (**515**).

If examining a new watch, it may be found necessary to form inclined notches at the edge of the cocks or near the centre-hole of the plate so as to see the action of the depths. But it is important that the settings of the jewels are not disturbed, and indeed that enough metal is left round these holes to admit of their being re-bushed if necessary.

515. Invisible and doubtful depths.—These must be

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tested by touch in the manner explained at pp. 636—642 of the *Treatise on Modern Horology*, and the requisite corrections applied after having re-polished the pivots, &c., as may be necessary. We would observe that holes a trifle large are less inconvenient than those which afford too little play, providing the depths are in good condition.

516. Length of balance-pivots: centring the balance-spring.—Remove the endstone from the chariot and see that the pivot projects enough beyond the pivot-hole when the plate is inverted. Then remove the cock and detach it from the balance. Take off the balance-spring with its collet from this latter and place it on the cock inverted, so as to see whether the collet is central when the outer coil is midway between the curb-pins. Remove the cock endstone and endstone cap, place the top balance pivot in its hole and see that it projects a little beyond the pivot-hole.

Place the balance in the figure-of-8 calliper to test its truth, and, at the same time, to see that it is sufficiently in poise; it must be remembered, however, that the balance is sometimes put out of poise intentionally (see No. 8 in article **547**).

517. Play of train-wheel pivots.—Allow the train to run down: if it does so noisily or by jerks, it may be assumed that some of the depths are bad in consequence either of the teeth being badly formed, or the holes too large, &c. To test the latter point, cause the wheels to revolve alternately in opposite directions by applying a finger to the barrel or centre-wheel teeth, at the same time noting the movement of each pivot in turn in its hole; a little practice, comparing several watches together, will soon enable the workman to judge whether the play is correct.

The running down of the train will also indicate whether any pivots are bent.

Now remove the barrel-bar with its several attachments.

518. Centre-wheel: bad uprighting.—Remove the third wheel, and, if necessary, test the uprighting of the

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centre-wheel by passing a round broach or taper arbor through it, and setting the plate in rotation about this axis, holding a card near the edge while doing so. This will indicate at once whether the axis of the wheel is at right angles to the plate.

When a marked deviation is detected, or the holes are found to be too large, they must be re-bushed and uprighted again (**625**).

When, however, the error is but slight, the axes may be set vertical by bending the steady pins a little, in doing which proceed as follows :—

Set the bar in its place alone, the screw or screws being a little unscrewed, and rest the side of the bar opposite to that towards which it is to be bent against a piece of brass held in the vice, and strike the farther edge of the plate one or two sharp blows with a small wooden mallet. Experience alone can teach the workman to proportion the blow so as to obtain a given amount of deviation, and must enable him to ascertain whether it is desirable or not to pass a broach through the steady-pin holes before operating as above explained. Some discretion is essential in practising the method.

It is important that the centre pivots project beyond the holes in the plate and bar. A circular recess is turned round the outer end of each of these holes so as to form reservoirs for oil. Owing to the neglect of these simple precautions, which are so easy to take, many watches, especially those that are thin, come back for repair with their centre pivots in a bad state, because the oil could not be applied in sufficient quantity, and has been drawn away by the cannon-pinion or the steel shield.

If the watch has a seconds-hand, ascertain by means of the calliper that its wheel is upright. Finally, examine each jewel to see that it is neither cracked nor rough at the edges of the hole.

519. The barrel: to take down and repair.—The side spring, which must not be too strong, should reach with

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certainty to the bottom of the spaces between the teeth of the ratchet, and this latter should be held steadily in position by the cap. The barrel may be made straight and true on its axis by the methods explained in articles **560—2,** the arbor having been previously put in order if required (**581—4**). It is a good plan after making the extensive repairs here spoken of to again test the barrel and centre-pinion depth, either by touch or by drilling a hole for observation.

The screw of the star-wheel must not project within the cover nor rub against the dial; it must be reduced if either

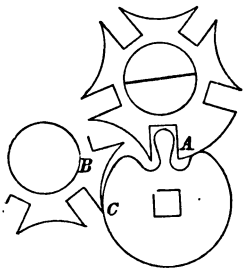

Fig. 20.

case presents itself. The action of the stop-work must be well assured, especially when the actual stop occurs. It is a good plan to, as it were, "round-up" the star-wheel and finger-piece, with an emery stick, supporting them on arbors. There must be no possibility of friction between the finger and the bottom of its sink.

520. To test the stopwork.—Take up the winding square of an arbor, with the barrel, &c., in position, in a pair of sliding tongs or a Birch's key; hold the tongs between the last three fingers and the palm of the left hand, the first finger and thumb being applied to the circumference of the barrel so as to rotate it, first in one direction and then in the other. During this movement, take a pegwood

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point in the right hand, and try to turn the star-wheel *against* the direction in which it would be impelled by the finger; the position is indicated by B in the annexed figure 20.* The tooth that is just going to engage with the finger will thus be caused to take up the worst possible position for being turned, and thus, if the action proves to be satisfactory for each tooth, we may rest content as to the future; providing, of course, that the engagement takes place square, and there is no tendency to cause distortion of the metal. When the corner of C is stopped against the convex tooth of the star wheel, the finger should be free in a space, and directed towards the centre of A. By holding the sliding tongs in a vice both hands can be kept at liberty.

For details in regard to the examination and repair of keyless mechanism, see articles **538, 604—5.**

ACCESSORIES OF USE SPECIALLY TO BEGINNERS.

521. To facilitate the work by securing order in taking to pieces and cleaning, preventing the screws from being mixed, &c., it is a good practice to prepare beforehand one or more boards, in which grooves and holes are made in positions to correspond with those of the several pieces on the plate of the watch, as indicated by fig. 1, plate IX.

The round holes receive the cock and bar screws, which may be cleaned while the other parts are in the benzine solution. (Two holes are shown side by side for each bar and cock, so that the same plate will serve for a large and small watch.) The oval or circular hollows at *a* and round *m* receive the cap screws, and *m* the shield; *c*, *c*, *c*, hold the screws of the side spring and star-wheel and the finger-piece pin; *j* is for the screws of the top endstone, and *n* for those of the bottom endstone, &c.

* Tripplin's Lecture on Examining Geneva Watches. *Horological Journal*, Vol. XIX. (1878), p. 120.

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It may be well here to mention the very convenient divided deal boxes for holding the several parts of a watch when taken to pieces that are in general use by watchmakers. They are of foreign manufacture, and measure about six inches by four, and one inch in depth, thus being large enough to contain all the parts of any ordinary watch.

At first every young watchmaker will find the advantage of noting on paper bearing the number of the watch the successive operations that have to be done. He will then merely have to strike them out one by one as the work progresses. As he becomes more practised he can dispense with this auxiliary.

CLEANING THE WATCH.

522. Whatever system of cleaning is adopted it is essential that it be concluded by passing a pegwood point into each of the holes.

Brilliancy is given to the surfaces of cleaned pieces by passing a carefully kept fine brush over them. A brush that is greasy can only be cleaned by soap and water, and a new brush is prepared for use by passing an inclined cutting edge over the ends of its bristles so as to taper them off to fine points, and to remove knots due either to hard parts or to bristles becoming united. This preliminary treatment is completed by charging the brush with French chalk, and rubbing it vigorously on a dry crust of bread until the brush can be passed over a gilded surface without scratching it. The bristles are maintained in good condition by the same treatment. Billiard chalk is also very effective for this purpose, and the greater number of cavities there are in the crust the better it will act. Groat bread seems to be preferable to that made from wheat, because the latter contains greasy particles which prevent the brush from being kept thoroughly clean. A burnt bone is an excellent substitute for the crust, and has the advantage of causing

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the brush to impart a very brilliant appearance to objects to which it is applied.

523. To clean with a brush.—This method is less used now than formerly, as it can be adopted with safety with the old-fashioned gilding, but is too severe for the thin galvanic coats that are applied at the present day. It may, however, be resorted to for getting up the surface of polished brass wheels, for example.

Put some French chalk or powdered hartshorn (which can be bought at a chemist's) in pure alcohol. Shake the mixture; and with a fine paint brush coat the object with a small quantity of it, subsequently brushing the surface with a brush that is in very good condition. Polished wheels may be made to present a very brilliant appearance by this means, but their teeth and the leaves of pinions must be afterwards carefully cleaned.

The French chalk and hartshorn are all the more effective according as they have remained a longer time in the alcohol; doubtless owing to the fact that the hard grains met with in them are then more completely dissolved.

524. Soaping.—It is advisable to use a soap that quickly produces a good lather; and the object is held in the hand and cleaned by rubbing with a soft brush charged with this lather; then immerse first in clean water, and subsequently in alcohol, moving it about in each: it may be left for a few seconds in this latter, and, on being removed, is dried with a fine linen rag or soft muslin. A stroke with a soft brush in good condition will give brilliancy to the surface.

As water sometimes dissolves the soap very slowly, it is desirable that it be employed warm.

If about to soap polished wheels, the surface must be first got up with a buffstick and rouge, or by brushing with hartshorn.

The balance-spring may be cleaned by laying it on a linen rag doubled, and tapping it gently with a brush charged with lather; then dipping in water and alcohol in succession.

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The alcohol may be used hot or cold ; its action is, however, more rapid and effective in the former case. But there is no occasion to use hot alcohol except when dealing with substances such as wax, that resist its action.

525. Essences and benzine.—The employment of essences in cleaning watches is becoming more general every day. They are to be obtained at all the tool-shops, together with full instructions in regard to their use. A few observations may nevertheless not be out of place here.

The objects are left in the solution for a few minutes in order to allow all adhering matter to dissolve, but they must not remain too long, as certain qualities of benzine, &c., are apt to leave stains. Dry the pieces on removing them and finish by passing over a fine brush that has been charged with chalk and subsequently rubbed on a hard crust or burnt bone ; as has already been observed, this will produce a brilliant surface on either gilding or polished brass.

The following composition, the ingredients of which can be obtained at any chemist's, has been strongly recommended to us by a clever watchmaker :—

90 parts by weight of refined petroleum.
25 „ „ sulphuric ether.

The objects are immersed for several minutes ; indeed, they may remain for a longer period without danger, and on removal from the bath are found to be clean and bright.

It must not be forgotten that many of these essences are liable to ignite with the mere proximity of a lamp.

PUTTING THE WATCH TOGETHER AND FIXING IN CASE.

526. The three following rules must be observed in arranging a system of putting the watch together : (1) avoid taking up the same piece two or more times; (2) hold it lightly, as any pressure will produce a mark ; (3) keep it as short a

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time as possible in the fingers. Any linen rags used must be free from fluff, but rags of all kinds should as far as possible be replaced by certain kinds of tissue paper. The best kind will be that which, while securing a given degree of pliability, will best prevent heat and moisture from passing through. Blue-shaded tissue paper should be avoided as it is often found to encourage the formation of rust on steel-work.

527. The following order is adopted by some excellent watchmakers in putting together the ordinary form of Geneva watch : it may be adopted exactly or modified as experience dictates.

Commence by putting the several parts of the barrel together, attaching it to the bar and observing the directions given farther on (**531**) in regard to the distribution of oil. Owing to the position of the stop-finger, it is sometimes found that the mainspring must be set up either one-quarter or three-quarters of a turn. Very often one quarter is not sufficient, and in such cases it is necessary, before putting together, to ascertain that the spring admits of at least 5 or $5\frac{1}{4}$ turns in the barrel. If it will not allow this amount, and yet has to be set up three-quarters of a turn, too great a strain will come upon the eye of the spring in winding. (See page 677 of the *Treatise on Modern Horology*.)

Fix the chariot with its endstone on the under side of the plate.

Replace the fourth wheel, making sure that it is free and has no more than the requisite endshake and is upright. Then the escape-wheel, testing it in a similar manner. See that the teeth have sufficient freedom on both sides of the cock passage, then make the two wheels run together with a pair of tweezers or pegwood in all positions of the plate to make sure of everything being free.

528. After attaching the index and endstone to the balance-cock and the balance-spring to the balance (observing that the centre of the stud is against the dot on the balance

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rim), place some oil in both the balance pivot-holes (**533**); adjust the balance to the cock after placing a drop of oil in the cylinder (though a much better plan is that given in article **533**), and set in position on the plate. Some workmen apply a drop of oil to the top of the escape-wheel pivot-hole before setting the balance-cock in its place, but others prefer only to add the oil after the escapement has been tested.

Placing a small piece of paper first between the balance and cock, and then between the balance and plate, ascertain whether the escape-wheel occupies its correct position in reference to the cylinder, in order that the escapement may act properly. This test is especially necessary in dealing with very thin watches or those in which the cylinder banking slot is exceptionally narrow.

The barrel bar is now fixed to the plate.

529. Set the third wheel in its place, and lastly the centre wheel, after putting a little oil on the shoulder of its bottom pivot. Before putting the bar over it, apply oil to the top pivot in a similar manner; then screw it down. After this is done screw on the third wheel cock.

Now apply a small quantity of oil to the two centre pivots and very lightly to the others that have not already been oiled; give a turn to the key and listen to the tick of the watch in all positions. This should always be done before replacing it in the case.

After passing the slightly-oiled set-hands arbor through the centre pinion, and adapting the cannon-pinion to its end, reverse the watch, passing the end of the centre arbor through a hole in the riveting stake, so that the watch is supported on the end of the cannon pinion; a light blow of the hammer on the square end of this arbor will then suffice to drive the cannon-pinion home. Some do this before replacing the movement in its case, and some after.

Add a little oil to such pivots as have not already received enough, and fix in their places the remaining parts of the

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motion work, the dial and hands: the watch then only requires to be timed.

Precautions to be observed in applying oil.

530. The method of distributing and applying the oil is of more importance than might be thought, and has a very marked influence on both the time of going and the rate.

Oil that is very fluid may be used for the escapement and fine pivots where only a small quantity is needed and the pressure is slight; but it is not suitable in other places on account of its tendency to spread and thus to leave the rubbing surfaces.

If too much oil is applied the effect is the same as if there had been too little; it runs away and only a minute quantity is left where it is wanted. For an account of the various kinds of oil see articles **157—9.**

531. *Barrel.*—It is not enough to apply oil to the coils of the spring; some must also be placed on the bottom of the barrel. Before putting on the cover, moisten the shoulder of the arbor-nut that comes in contact with it with oil: by doing so, when oil is applied to the pivot, after the cover is in its place, this oil will be retained at the centre of the boss in the cover. Moreover, it will not then be drawn away by the finger piece, passing from this to the star-wheel.

The oil applied to the upper surface of the ratchet to reduce its friction against the cap must not be in such quantity as to spread on to the winding square. It is a good plan to round off the lower corner of this cover.

532. *Centre-wheel.* — The observation made above in reference to the oil applied to the barrel cover may be repeated here. By proceeding as explained in article **529,** and adopting the precautions mentioned at the end of article **518,** it is possible to make sure of the pivots lasting for a long period.

533. *Escapement pivots: Cylinder.*—When the drop of

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oil is introduced into the oil-cup of the balance pivot-hole, insert a very fine pegwood point, so as to cause the descent of the oil; a small additional quantity may then be applied When this precaution is not taken, it frequently happens that in inserting the balance pivot its conical shoulder draws away some of the oil, and there is a deficiency both in the hole and on the endstone.

As has been already noticed (**528**), some workmen place a single drop of oil within the cylinder, and when the escape-wheel advances each tooth takes some up. This method is unsatisfactory, because the earlier teeth receive such a quantity of oil that it runs down the pillars where it is useless and merely tends to increase the weight of the wheel. A much better plan is to put a] very small quantity in the cylinder and on the flat of each tooth or every second or third tooth. It will thus be evenly distributed, and will not tend to flow away.

The escape-wheel pivots require but a small quantity of oil. It often happens, however, that, owing to carelessness, the workmen applies too much, and it runs down to the pinion. The leaves will thus become greasy and stick while the pivots are running dry.

TO EXAMINE AN ENGLISH MOVEMENT.

534. As has been already observed in article **510**, many of the remarks made in speaking of the Geneva movement are equally applicable to that of English construction, and any intelligent watchmaker, on reading articles **507—520**, will be able to select for himself whatever has a bearing on the English watch without difficulty. It will be well, however, to supplement it by the special directions contained in the four following articles :— *

535. Case, glass, dial, cap, dome.—In addition to the

* *Horological Journal*, Vol. XXIV. (1881), p. 19.

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points specified in articles **508—9**, the following require attention. See that the position of dial is not altered by closing down the bezel, that the fusee dust-cap does not touch the dome or cap ; and that the diamond endstone or other jewelling of the balance-cock is free of the case. In ¾-plate watches the chain is occasionally found to rub against the edge of the case, or the top-plate to press against the bottom edge of the same, causing the train to bind. See that the balance and chain and the fusee great wheel are free of the cap where one exists : the chain is especially liable to rub after the breaking of a strong spring, which may cause the barrel to bulge, when it may also rub against the potence. Ascertain that none of the dial-plate feet or pins touch the train, that the hour wheel is clear of the third and fourth wheel bar, and the minute wheel out of contact with the dial-plate and not pressed by the dial. See that the third wheel is free in its hollow, and that the balance, more especially in oversprung watches, is clear of the barrel.

536. Movement.—The regulator or index must be tested, especially in watches that are undersprung, at several points between "fast" and "slow," to see that it nowhere approaches too near to the spring, is held with sufficient firmness, and that it never comes near enough to the guard pin for contact to occur. See that the potence screw and steady-pins do not project, and that the barrel does not touch the name-plate, balance-cock, top-plate hollowing or great wheel.

Before taking off the top-plate, notice the position of the detent in the steel wheel, and the amount of its endshake ; the wear of the holes, and freedom of the train wheels ; the position of the third pinion with respect to the centre wheel, and that of the escape wheel to the lever : see that the banking pins are not loose or bent ; that the guard pin, which protects the balance staff when the chain breaks, is near enough to the barrel and the potence. When the watch

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is taken to pieces, any loose pillars or joints must be secured, pivots examined to see whether worn or bent, and those working on endstones that they come through the holes. The fourth wheel pinion must be free in the hollow of the pillar plate and the centre wheel in its hollow; a similar examination also must be made of the collet and pin which secure the great wheel to the fusee. If a chain is broken near the barrel end, the stopwork is probably defective or the spring too strong.

The following faults may be met with in the English stopwork. The stop may come opposite the fusee snail too soon or too late, allowing one turn too few or too many of the fusee; or the back of the snail may butt against the stop, and thus stop the watch after going for a few hours. Overwinding sometimes occurs in consequence of the stop-spring being locked between the shoulder of the stop and its brass stud; and the blade of the snail or the end of the stop may be worn or bent in cleaning.

In ¾-plate fusee watches, see that the balance does not come too near to the fusee, fourth wheel, centre wheel, and sometimes the escape-wheel. It is to be observed that the breaking of a mainspring sometimes causes certain teeth of the great wheel to be strained.

537. Escapement.—Very full details in regard to the method of examining a lever escapement, as well as of the causes of stoppage and variation in connection with it, will be found at pages 463—470 of the *Treatise on Modern Horology*. It may be well to note the few following particulars that should always be attended to. See that ruby-pin and pallet stones are firmly set, that neither pallets nor roller is loose on its staff, and that the lever and pallets are rigidly fixed together. The guard-pin must be firm, the balance well riveted to its collet, the spring collet sufficiently tight and the curb pins firm. If there is a compensation balance, ascertain that each screw is tight. The precautions to be observed in regard to the balance-

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spring are given in article **513** (see also articles **655—666**).

538. Keyless work.—So great a variety of arrangements of the mechanism for winding watches at the pendant is met with at the present day that it would be impossible to give detailed directions in regard to their examination; the following general remarks, however—mainly taken from the work of M. A. Philippe on Keyless Watches*—will be found of value in directing attention to the points which most require it, and will suffice for any intelligent workman. It should be observed at the outset, however, that the adjustment of keyless work is almost entirely a question of depths, and the workman who has thoroughly mastered this subject as explained in the *Treatise on Modern Horology*, (see also articles **628—637** in this volume) will rarely experience any difficulty in dealing with keyless mechanism.

Carefully observe each depth, &c., in succession, to make sure that no prejudicial friction occurs either between teeth or by contiguous parts coming in contact. All springs should act solely in the direction in which pressure is required of them. Special attention should be given to the intermediate steel wheel for communicating motion to the cannon-pinion, when this exists, as it is permanently in gear with the train, so that any unevenness of the depth will affect the rate: if the minute wheel have too much endshake or play on its stud, it is apt to ride on the intermediate steel wheel. The friction of the cannon-pinion on the set-hands arbor must not be excessive, since it would involve too great a strain on the teeth of the minute wheel, nor too slight, since the hands would be liable to be displaced on releasing the set-hands stud. If the intermediate wheel has too much endshake, limit this by an excentric screw overlapping its edge.

Test the spring of the set-hands stud, to see that it is not

* *Les Montres sans Clefs* (Geneva).

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too strong or too weak and that it moves parallel with the plate. Failure in this latter particular might lead to its rising on to the rocking-bar or other piece on which it acts.

The winding pinion depth must be examined to see that it is neither too deep nor shallow. A method of correcting such a fault is given in article **637.**

The set-hands stud-spring must be strong enough to resist any accidental pressure on the stud, but, on the other hand, the strength must not be excessive, as the spring will then be all the more liable to break, besides causing inconvenience when setting the hands. The course of the spring should be banked at the point which gives a good depth between the winding and intermediate wheels. The minute-wheel stud must be firm in the plate, as any accidental binding might otherwise unscrew it, occasioning the breakage of the dial. When the minute hand is carried by the set-hands arbor, and not by the cannon pinion, care is necessary in fitting this latter, for if too loose it will rotate in setting the hands without carrying the minute hand round, and the minute and hour hand will cease to agree.

It is important that attention be paid to the application of oil to keyless work, as, in its absence, rust rapidly forms, and the mechanism becomes bound. Of course, all bearing surfaces, such as the interior of the pendant, intermediate and minute wheel studs, studs or screws of the rocking bar or other surfaces on which wheels rotate, must be lubricated; an equally important point is to liberally oil the teeth of the winding pinion and the bevel or crown wheel that engages with it. The application of a little oil inside and outside the cannon pinion must not be forgotten.

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TO RAPIDLY TIME A WATCH OR CLOCK.

539. Very full explanations are given in the *Treatise on Modern Horology* as to the mode of regulating a timekeeper by counting the number of vibrations (see pages 235 to 240 and 788 to 790), and reference is therein made to the Vibration Counter which will be found described in article **541.** Nevertheless, it seems desirable to supplement the information there given by further details, since we have observed that, either from want of patience or method, many watchmakers are not always successful in counting the vibrations.

540. To practise counting vibrations.—At the outset it is to be observed that to each vibration to the right there corresponds one to the left, so that it is only necessary to observe those in one direction, or else to count one for each two impacts of the escapement, in a minute (or half-minute), in order to ascertain the number of vibrations.

14,400 vibrations per hour correspond to 4 per second; that is 240 per minute, or 120 per half-minute, and the half of this number is 60.

Similarly, a 16,200 train would give $4\frac{1}{2}$ vibrations per second; or 270 in a minute, the half of which number is 135.

An 18,000 train giving 5 vibrations per second or 150 per half-minute, would count 75 in this interval of time.

This being understood, the required number of vibrations is to be ascertained as follows :—

The movement is placed in such a position that the light is reflected from an arm of the balance, so that, by reference to some fixed point (such as the side of the balance-cock, the stud, &c.), each return of the balance can be noted and counted. A very little practice will remove any difficulty

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that may be experienced in doing this. When the requisite skill has been acquired, one can listen to the impacts of the escapement while continuing to count, and in order to determine with greater facility the correspondence of the position of the balance with successive pairs of vibrations, close the eyes from time to time while still counting. On opening them, the accuracy of the coincidence can be at once tested by the sight, and, with a little patience, it is possible to count the double vibrations with certainty in this manner both by the eye and ear; it is only necessary when nearing the end of the minute or half-minute to continue counting aloud, while keeping the eye on the regulator: for the ear will guide the voice, which will thus accurately reflect the motions of the watch.

The above explanations will be sufficient to enable any watchmaker of average intelligence to acquire the power of counting vibrations, either in the manner here recommended or by modifying it in any manner that may suit his temperament. This power, when once acquired, will be of very great assistance in his daily work, for before taking a watch to pieces that requires repair, he can in one or two minutes ascertain the number of vibrations it should make; he will thus be enabled to regulate the watch almost instantaneously when the necessary repairs have been completed. We would again observe that the main point is to educate the ear to ignore each alternate vibration, and thus to count only the intervals of the balance being in the same position and the same phase of its motion.

541. Vibration counter.—Leclerre's Vibration Counter, to which reference has already been made, is shown in figure 21. R is a ratchet-wheel with 30 teeth, mounted on a vertical plate, so that it can rotate freely. A pawl, *v*, prevents its movement except when forced forward one tooth at a time by depressing the spring gathering-click, *p*, a finger being applied to the button, *o*, each time the word "ten" is uttered. The number of teeth advanced thus

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affords a record of the vibrations as explained at page 237 of the *Treatise*, without there being any necessity to go into higher figures.

542. To regulate a watch.—Place the movement near to a regulator or watch indicating seconds, in such a position that the eye can easily observe the periodical return

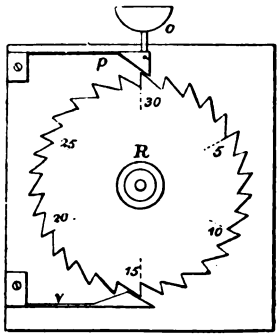

Fig. 21.

of an arm of the balance as already explained, and commence to count, always starting from the instant at which the seconds hand points to zero. Then count steadily 1, 2, 3, 4, &c., until this hand reaches 30 seconds.

Assume, as is very commonly the case, that the balance should make 18,000 vibrations in an hour, or 150 in a half-minute, and that, on counting its vibrations, we find 65 double vibrations, or 130 beats, whereas it should give 150. It is thus 20 beats slow. Advance the index, and repeat the operation; and so on till the regulation is effected.

A greater degree of accuracy will be secured by counting for a longer period, say one, two, or three minutes; but when this is done, it is advisable, in order to avoid confusion, to re-commence at one after each 30 or 50 have been counted, because all that is required is the final deviation.

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Remarks.—(1.) All men are not equally quick of perception, so that, in counting and uttering the word *one*, it will be found to correspond with the end of the first beat in the case of some observers, and its commencement with others. By practising on a well regulated watch, a watchmaker can determine to which of these classes he belongs. If to the second, he should double the *one* at starting, in other words, he should count thus:—

1, 1, 2, 3, 4, 5, &c.

(2.) Advantage may be taken of the principle of the sounding-board by placing the watch on a sonorous body which will make the vibrations louder, or by placing between the plate of the watch and the ear a rod that is a good conductor of sound. By either or both of these means, the operation is rendered very easy, especially if the vibration counter recording the tens (**541**) is employed.

543. Another method of regulating a watch.—When the movement is in going order, arrest the balance and make a mark with rouge on one arm of the escape-wheel. Release the balance when the seconds hand of the regulator crosses 60. Observing the number of revolutions that should be made by the escape-wheel in a given time (it would be six turns per minute with an ordinary 18,000 train), count its revolutions while the fourth wheel makes one complete turn; indeed, even this counting may be avoided by making a rouge mark on its edge where it corresponds with the mark already made on the escape-wheel. If after two or three minutes these two marks are found to occupy similar positions at the instant the seconds hand of the regulator crosses 60, the watch is to time. If there is any difference it is easy to ascertain whether this indicates a gain or a loss, and the index is moved accordingly.

544. To regulate a clock.—The timing of timepieces by counting vibrations is much more easy than that of watches.

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Before removing the pendulum count the number of its vibrations during two or three minutes. This time will be sufficient to afford a guide in regulating the clock after it has been repaired.

If the suspension has been damaged, estimate the length of the pendulum and thence its number of vibrations by means of the Table of Lengths of the Simple Pendulum (*Treatise on Modern Horology*, pp. 817—819); but this will only afford an approximation.

In most modern timepieces the escape-wheel makes 120 revolutions in an hour, or two in a minute (**634**). Hence we have two modes of timing.

(1.) Having made a light mark on the circumference of this wheel opposite to a fixed point, observe if the coincidence is maintained after intervals of two or three minutes.

(2.) Multiply the number of the escape-wheel teeth by 2, and the product by 120. This gives the number of oscillations the pendulum should make in an hour. Thence deduce the number it should make in two minutes, or the number per minute can be obtained by multiplying the first product by 2, and it only remains to count the number actually performed in any definite interval.

545. Guilmet's Synchrometer.—The object of this appliance is mentioned at page 790 of the *Treatise*. When a clock is to time its pendulum makes a certain definite number of oscillations per minute, dependent on the train. If, therefore, before taking it to pieces a comparison pendulum be set to make the same number of oscillations as that of the clock, or if the former be set to make the number which the train shows that the clock pendulum should perform, it can be used as a term of comparison for setting the clock to time after it has been cleaned. This is the principle on which the synchrometer is based. A pendulum is lightly supported on a frame, and has an adjustable rod sliding in a tube, and graduated so that it can be firmly set without difficulty to give the various periods of oscillation commonly

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met with in timepieces. The pendulum is hung freely without any train to drive it, and continues to oscillate for two or three minutes, quite long enough to ascertain whether agreement is maintained between the two pendulums.

546. Other methods of regulating a clock.—Various plans have been recently proposed for rapidly timing a clock, all based upon one idea: namely, the temporary addition of a seconds hand for purposes of observation. That suggested by M. Jacomin is recommended by its simplicity.

Having removed the pin and washer that maintain the minute-hand in position in an ordinary timepiece, replace them by a light brass cap that can be fixed by a screw or in any convenient manner, so that a fine steel pin projecting from it shall be accurately in the axis of the minute wheel. Part of a watch movement, comprising only the centre, third and fourth wheels with seconds hand attached, is supported in front of the clock dial, so that this pin can be inserted in place of the set-hands arbor, and it is evident that, if the clock is to time, the seconds hand should perform one revolution per minute as it will form part of the clock train. The length of pendulum must, then, be varied until this condition is found to be satisfied.

TIMING IN POSITIONS.

(Horizontal and Vertical.)

547. To adjust a watch so that it has the same rate when placed first in a horizontal and then in a vertical position is a delicate and often difficult operation; thus it is seldom found to be properly done in ordinary watches. We would refer the reader to the *Treatise on Modern Horology* for information concerning this subject. Pages 234 and 788 have special reference to watches of average quality, and pages 781 to 783 refer to high-class work. It will be well here to

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summarize such of the directions as have a bearing on every-day work.

The rates in a vertical and horizontal position are made identical or nearly so by equalizing the resistances that interfere with the motion of the balance in the two cases, and by taking advantage of the displacement of the centre of gravity of the balance-spring.

Satisfactory results will be obtained in most cases by employing the following methods, either separately, or two or more together, according to the results of experiments or the rates, the experience and the judgment of the workman :—

(1.) Flatten slightly the ends of the balance pivots so as to increase their radii of friction ; when the watch is lying flat the friction will thus become greater.

(2.) Let the thickness of the jewel-holes be no more than is absolutely necessary. It is sometimes thought sufficient to chamfer the jewel-hole so as to reduce the surface on which friction occurs ; but this does not quite meet the case since an appreciable column of oil is maintained against the pivot.

(3.) Reduce the diameters of the pivots, of course changing the jewel-holes. The resistance due to friction, when the watch is vertical, increases rapidly with any increase in the diameters of pivots.

(4.) Let the balance-spring be accurately centred, or it must usually be so placed that the lateral pull tends to lift the balance when the watch is hanging vertical. In this and the next succeeding case it would sometimes be advantageous to be able to change the point at which it is fixed ; but this is seldom possible.

(5.) Replace the balance-spring by one that is longer or shorter but of the same strength ; this is with a view to increase or diminish the lateral pressure, in accordance with the explanation given in the last paragraph.

(6.) Set the escapement so that the strongest impulse corresponds with the greatest resistance of the balance.

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(7.) Replace the balance. A balance that is much too heavy renders the timing for position impossible.

(8.) Lastly, when these methods are inapplicable or insufficient, there only remains the very common practice of setting the balance "out of poise."

If there is a gain in the vertical hanging position of the watch, slightly reduce the *lower* side of the balance; the oscillation will increase somewhat in extent, and there will be a losing rate in this position.

The converse must be done in the opposite case.

When the vibration exceeds a whole turn, the changes will be the reverse of those above indicated. This fact must not be forgotten, especially in regard to the duplex and lever escapements, which may at first make a vibration of more than a turn, and subsequently less, according to the state of the oil.

We would again observe that the timing of a watch for position presents some difficulty, and it will only be after making a number of trials and studying the articles already quoted, that the watchmaker will be able to accomplish it with certainty.

Note on the proportions of balances.

548. Two very important elements in the timing are the weight and dimensions of the balance; it is, then, necessary that a watchmaker should practise himself in observing their relative values, and the effect of increasing one at the expense of the other on timing, and more especially on timing for positions.

The *sensibility* of a balance to variations in the motive force, and the time that elapses between the initial short vibration and the first that is of normal extent, a time that is approximately constant, will serve as criteria. A balance that is very sensitive to variations in the motive force is generally too small; and one that attains to the normal arc

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of vibration almost instantaneously, is, as a rule, too light. The converse effects would indicate that the size and weight were excessive.

In order that he may be able to practically apply these remarks, the workman should gain experience by making observations on several watches whose rate is known to be good, in the following manner. In regard to *weight:* Stop the balance at the position of rest of its spring, then release it and count the number of vibrations up to the point at which the normal arc is attained; the extent of this must have been previously recorded on the plate with rouge marks. Record the number thus obtained in a table opposite to the dimensions of the balance, and, by comparing these dimensions with those of another balance of equal size, the weight can be ascertained and also recorded. In regard to *size:* Pass through the centre pinion a kind of short screw arbor carrying a large thin ferrule, on which a cord supporting a weight is coiled. Fixing the movement in a movement-holder, set it in a vertical plane and observe the extent of the vibrations of the balance with different weights attached to the cord. These arcs should also be recorded in the table opposite to the dimensions of the balance.

With sufficient practice the watchmaker will be enabled to judge at a glance whether the weight and size are well proportioned. (See the *Treatise on Modern Horology*, pp. 240—243 and 719.)

TO DE-MAGNETIZE THE STEEL-WORK OF A WATCH.

549. The following method of removing the magnetism from a watch that has been accidentally brought under the influence of a powerful magnet is proposed by Professor A. L. Mayer in the *Scientific American*,* to which the reader who is desirous of obtaining complete details must be referred.

* *Scientific American*, Vol. XLI. (1879), p. 227.

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We shall not here enter more fully into the subject than is necessary to indicate the manner in which a watchmaker may restore the steel-work to its original condition.

Take a delicately suspended magnetic needle, say a mariner's compass, the length of which is about equal to the diameter of the watch, and lay it on a table. Now place the watch to be operated on, which should not be going, on the table close to the needle and on either the east or west side of it, having previously turned the box round until the needle points to zero. Taking care not to vary the distance between the centres of the watch and compass, observe the number of graduations to which the north end of the needle is deflected with each figure on the dial brought in succession nearest to the compass: it is also necessary to note whether the deflection is towards the east or west.

For example, assume that the watch is on the east side, and that, with noon nearest to the compass, the north end of the needle is turned 12° to the east, that is, towards the watch. This shows that some point in the watch in the neighbourhood of the number XII. on the dial possesses what is known as "north polarity," and if the deflection had been to the west the polarity would have been "south."

550. To take an example. Let the results of a series of trials with the several hours in succession towards the compass be as given in the following table:—

Hour nearest to the Compass	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Angle of Deflection ...	5°	18°	72°	56°	22°	5°	17°	16°	16°	20°	24°	20°
Direction of Deflection...	E	W	W	W	W	E	E	E	E	E	E	E
Hence Polarity is ...	N	S	S	S	S	N	N	N	N	N	N	N

It will be seen that the greatest deflection westward

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corresponds to three o'clock, and, in the easterly direction, to eleven o'clock. This shows that the strongest south and north polarity are respectively in these directions. The first thing to be done is, then, to eliminate this particular magnetism. Placing a bar magnet in a horizontal direction, approach the watch to its south-seeking end in such a manner that a line X X^1, fig. 22, through the axis of the magnet, will pass through the centre C of the watch, the figure XI, which marks the point of extreme north polarity, being nearest to the bar magnet. Now cause the watch to oscillate

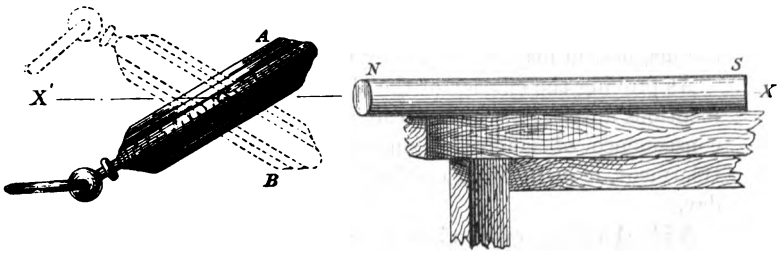

FIG. 22.

so that it alternately takes up the two positions A and B, and, when this has been several times repeated, bring III in a similar manner near the north-seeking pole of the bar magnet, oscillating the watch in the same way. Again try the watch with the compass, repeating the above operations if necessary until the readings are somewhat as follows :—

Hour nearest to the Compass	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Angle of Deflection ...	5°	4°	0°	5°	8°	2°	4°	4°	2°	1°	0°	2°
Direction of Deflection...	E	E		W	W	W	E	E	E	E		E
Hence Polarity is ...	N	N		S	S	S	N	N	N	N		N

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These figures show that, in counteracting the polarity at III and XI, the magnetic action of the watch in all other positions has, as might indeed have been anticipated, materially diminished. Such a condition of things will of course not be attained at once, and it may even happen that the polarity at the two points III and XI is reversed; in such a case it is only necessary to oscillate the III in front of the south-seeking pole instead of the north.

The last table shows that a maximum south polarity is now at V and north at I. These points must therefore be operated upon in the same manner, and, by proceeding in this manner, and successively eliminating the worst points, the magnetism may be effectually removed.

As proving the efficacy of the above method, Prof. Mayer mentions a case in which a watch lost one hour in six in consequence of magnetization, and yet, after the above treatment, it resumed its original rate of about a second per day.

551. Another method.—A second method of procedure has recently been described in the same journal by H. S. Maxim. He employs a specially arranged apparatus, based on the principle that if a watch or other object be subjected to rapid alternations of magnetism, while gradually withdrawing it from the influence of the magnetic poles, the distance ultimately becomes so great that the reversals are inappreciable, when the watch is found to be de-magnetized. A bar magnet is arranged to revolve in a horizontal plane round a vertical axis; the watch being placed in a small pocket opposite to the magnet, is caused to rotate in an ever-shifting vertical plane while the frame supporting it rotates in a horizontal plane. While these movements continue the watch carrier is gradually moved away from the magnet by the action of a long horizontal screw, and it is stated that watches that have been completely spoilt can be rendered perfectly free from magnetism by such an apparatus.

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PART VI.

PRACTICAL RECEIPTS.

552. The practical operations of the watchmaker are numerous and of a very varied character. Detailed instructions in regard to the proper conduct of a large number of them will be given in this part of the work, and frequent references will be made to the *Treatise on Modern Horology* as well as to the former part of this volume, whenever by so doing repetition can be avoided.

The operations herein discussed are often of so dissimilar a nature that it has been found impossible to classify them in a manner that will always ensure the reader finding the information he requires without waste of time; and any risk of this would seriously impair the value of such a hand-book as the present. A very full index has therefore been added, and when seeking for details concerning any particular operation, this should in all cases be first consulted.

THE PLATE.

553. To make a plate.—The sheet of brass having been prepared in the manner explained in article **103**, roughly rounded and smoothed on one face, is cemented to the chuck of a lathe. Turn out the other face of the plate very flat, and make the circumference square.

When using a mandril the face must first be roughed out, and then the plate is to be cemented to a perforated

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plate, so that it can be centred and finished. Smooth the exposed face with a well-set cutter (**396—8**), and turn the inside and outside of the edge; then make sure that the whole is concentric by a light cut with a cylindrical drill in the central hole. After removing and cleaning the plate it is set up in the dogs, and the face that has hitherto been untouched is gently dressed with the graver.

There will thus be left a narrow ring at the edge that is not touched by the graver: this may be levelled with a smooth-cut file, and the whole surface then smoothed as explained in article **171.**

If a mandril or lathe is not available, the plate must be cemented to an arbor of the form shown at Y, fig. 3, plate IV. The heel of this is received in a runner of the ordinary turns, while the point of the opposite runner is received by the hole in the centre of the plate, which is thereby held in close contact with the plate of Y, the revolution being, of course, produced by a bow. While the cement is still hot, a stick resting on the T-rest will serve to ensure the concentricity of the plate until it is set; and this setting may be rendered more rapid by the application of cold water.

Turn out the plate with a hooked graver made of a worn-out file, and, if the upper or under side does not run true, turn the portion that projects beyond the chuck with a graver, and, when the plate is removed, face the surface, taking the flat ring produced by the graver as a guide, and taking care to avoid altering any portion of it.

The smaller sinks can also be made in the same primitive manner, to which we have only drawn attention for the sake of watchmakers who are ill-provided with tools. But we would at the same time point out that, at the present day, there should not be a single one who does not know how to extemporize a lathe-head or to use the mandril.

554. Cocks and bars.—If it is required to make all the cocks and bars of a watch, prepare a *false plate*, the thickness of which is a trifle greater than that of the highest

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cock or bar; then turn on the under side a series of sinks to correspond with the thin portions of the cocks and bars. Cut the several parts out of this plate with a fine saw, and it only remains to shape their contours with a file.

The same method may be adopted if a number of identical cocks have to be made at a time.

THE BARREL,

Including arbor, stopwork, mainspring, &c.

555. To make a barrel.—Having trued both faces of the brass, and drilled a central hole rather less than that finally required and exactly perpendicular to the faces, turn away the brass from the inside (leaving a considerable excess of metal at the centre to form the shoulder), and form the ring on which the teeth are to be cut, if it is a going-barrel, either in the ordinary lathe on a wax-chuck or in the mandril. Then fasten the plane surface, which must be quite true, to a smooth plate that is of uniform thickness and has a hole in the centre to permit the passage of the pump-centre. Having fixed the plate by the mandril dogs, finish with well-set gravers (**396—8**): (1) the inside; (2) the external cylindrical surface both of the barrel and of the ring left for teeth; (3) the barrel-cover groove; and (4) with a fine-pointed cutter slightly enlarge the central hole. By this means it is possible to ensure that the barrel will turn true and in the flat. Smooth the inside, more especially the groove, the corner of which must always be carefully smoothed and polished.

The cutting of the recess in the barrel-cover (of a Swiss or French watch) that gives freedom to the motion work, as well as the recesses for the stopwork, will not present any difficulty when the workman is provided with a mandril with or without a slide-rest, or an ordinary pair of turns with lathe-head.

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When there is no slide-rest, the tool shown at D, fig. 17, plate VIII., can be used for making the groove. A strip of metal of rectangular section has a small cutter clamped in a slot in its surface at a slight inclination. By releasing the two screws of the clamp, this cutter can be advanced to any required extent, and in the strip of metal are two or three slots having different degrees of inclination, so that the one can be selected that corresponds with the depth of the groove.

556. A workman that is unprovided with a mandril can make a barrel as follows in the turns. Place a disc of well-hammered brass on a short arbor that is provided with a ferrule of large diameter; turn the two faces true to each other and make the outer cylindrical surface square to these faces. Now rough out the barrel internally as well as externally, taking care to leave an excess of metal over the entire surface, and using the ordinary and the hooked gravers (**323**) as required; but a ring of metal must be left at the centre rather less than a third of the internal diameter of the barrel and of the same thickness as the original brass, so that the barrel may be always replaced true on the arbor.

Now remove the barrel from this arbor, smooth its face with a soft stone and cement the face to a wax chuck in the lathe. This chuck should be provided with a short arbor at its centre, turned true, and fitting the hole in the barrel exactly. It will then be easy to finish the inside of the barrel either with a slide-rest, or with a hooked graver, and the little cutter for making grooves shown in fig. 17, plate VIII. If necessary, a lathe must be built up from the dead-centre turns in the manner explained in article **305**. All the depths can be determined with ease by means of the calliper described in article **243**.

557. To make the star-wheel sink.—This is easy on the mandril, the requisite degree of excentricity being given to the barrel-cover by means of the pump-centre. In its

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absence, proceed in the manner explained for making the barrel, waxing the cover to a flat chuck in which a recess has been made to receive the prominent central boss. The centring can of course be done as usual with a pegwood stick held against the rest (**405**).

558. The cover; form of the groove.—As in making the barrel, a thick ring must be left at the middle of the cover to be afterwards removed. After adjusting the disc on an arbor, which is just large enough to pass through, the cover can, in the absence of a mandril, be made entirely in the turns, except as regards the star-wheel sink (**557**).

Fig. 2, plate X., is an enlarged figure to show the mode in which a cover is held in its groove. The two are so formed that the cover shall pass into the recess with the least possible resistance, and yet be held firmly without a risk of rotation. It is nevertheless a good precaution to fix a pin in the rim so that it shall prevent such an accident.

559. Barrel-hook.—It is necessary to observe that a certain amount of caution must be exercised in regard to the barrel-hook, for at least three-quarters of those met with are badly made. A large hook projecting far into the barrel, as often occurs, occupies a needless amount of space, and at times occasions the breaking of the spring. One that is badly formed or does not project sufficiently allows the spring to escape. A hook should project rather beyond the thickness of the spring; if too thick the spring will be weakened at its eye; if too thin, it is liable to give when the pull of the mainspring is exerted on it.

The circumference of the barrel must be drilled through exactly midway between the bottom and the groove, in a direction that is slightly inclined, so as to resist the pull of the mainspring. A thread is cut in this hole with a conical tap, arresting its advance just before the full threads are reached, in order to make sure that the brass screw to be subsequently inserted shall hold firmly. Then tap the brass wire from which a hook is to be made. Allowing a length

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to project beyond the screw-plate equal to about one and a half times the thickness of the mainspring, file the two sides flat, round off the point, inclining it slightly backwards, and form the hook with a fine screw-head slitting or other suitable file; then remove the wire from the screw-plate and hold it in a pin-vice.

The angle *a* (c^1, fig. 3, plate X.), is now filed down so as not to project within the barrel; any burr that might interfere with its introduction is also removed, and the hook is then screwed into its place. It will be easy to ascertain whether the various heights, &c., are correct before screwing it tight home. Then screw the hook into position so that it requires the application of some force in doing so, and cut off the external portion level with the surface of the barrel, employing a sharp-cutting file. But if it appears necessary to withdraw the hook to make any alteration, this should be done before bringing it to the final position.

Some watchmakers do not take such precautions; they fit a piece of hard brass wire to the hole, bevelling off the end that is to form the hook; then cut off the wire nearly flush with the outer surface of the drum, and, resting the back of the hook against a piece of steel, give a blow with the hammer so as to bend the point of the hook. But this method, although expeditious, is not the best, and it does not always succeed.

560. To repair a barrel.—When the bearing shoulders are neither too thick nor too thin, and but little alteration is required, the method described in article **366** can be resorted to.

When the play or the endshake of the pivots is considerable, bush the holes with bouchons turned on a smooth taper arbor. They must not be riveted roughly as there is a danger of distorting the bouchon or of causing the bottom of the barrel to "cockle" (see articles **624—5**).

If there is any fear that the bouchon will be thus distorted or that the barrel will not run true after the operation, it

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will be well to employ large bouchons in which the hole is less than that ultimately required. Then centre from the circumference and enlarge the hole, at the same time trueing it (**411**).

Some practical watchmakers, if the bottom of the barrel is thin, or if special solidity is requisite, fear that the bouchon may become loose; they, therefore, enlarge the barrel-hole and make it square; then bush it with a piece of plain brass, and having centred the barrel by its circumference in the mandril or lathe, drill a central hole.

It is hardly necessary to observe that, when the holes in both barrel and cover require to be operated upon, a pin should be fixed so as to prevent the latter from rotating in its groove; so that before finally removing the barrel from the lathe, the cover can be put in position to have its centre accurately adjusted with a long pointed graver.

561. A barrel that does not run true.—The remedy for this has just been indicated: enlarge the holes and rivet in them bouchons that are either plain or have only very small holes. The two holes can then be accurately centred with a slide-rest and cutter of the requisite form.

In the absence of a mandril, the operation can be performed in an ordinary lathe, either using a wax chuck or one in which a recess has been turned of such a size as to just take the barrel.

The former is a very simple method, as any watchmaker can build up a suitable lathe for himself on an ordinary pair of dead-centre turns (see article **305**); and yet there are some workmen who, either from not possessing a mandril or ignorance as to how it should be used, set the barrel on a screw-arbor, and, after having topped the teeth, round by hand those teeth which have been touched. This method of procedure is longer than the former and gives results that are worse: moreover, since the screw-arbors are rarely themselves true, especially in regard to the cones which will be found to have a play on the axis, it is far better

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to set the barrel in cement on an arbor of the form C, fig 1, plate X., on the centre-pin of which the barrel-hole fits without play; the middle of the plate C must not be too thickly coated with cement.

562. Barrel out of upright.—Several methods may be resorted to for adjusting a barrel that does not turn flat on its axis. Assume that the holes are not too large, for it has just been shown that by bushing the holes and trueing them on the lathe, it is always possible to ensure that a barrel shall be true on its axis.

To true it without renewing the holes, first try turning the cover round in its groove by successive short stages, and test its truth each time; the arbor being clamped in a pair of sliding-tongs and a card held close to the teeth. If, after the entire circumference has been thus tested, no point is found that satisfies the requisite conditions, the edge of the cover must be gently hammered (a piece of silver paper being first laid on the anvil so as to avoid marking the gilding) on the side at which the teeth pass farthest from the card and the effect of the operation must be tested. This hammering should be done very carefully and little at a time, and if too great a strain is put on the cover to force it into the groove, some metal must be removed from the side opposite to that at which the hammering occurred. Hence, if the one side is too much extended in the first instance, so that a large amount of metal has to be removed from the opposite side, the operation is liable to be unnecessarily long and difficult. It is hardly necessary to observe that we are here referring to the modern form of going-barrel, in which the cover is on the opposite side to the teeth; in the older form, where the reverse is the case, the opposite edge of the cover must be hammered.

Sometimes a barrel that runs true on its arbor is found to incline when mounted on the plate: such a fault is due either to the barrel holes being too large or to the sink that receives the ratchet not being parallel to the plate. This sink must

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be trued in the mandril while in position, screwed to the plate of the watch.

For the method to be adopted in enlarging a barrel-hole, maintaining it at right angles to the top, see article **707.**

563. To adjust a post or curb in position.—Make a small punch, a front and side elevation of which are shown at *p*, *p*, fig. 5, plate X.; harden it and let down to a yellow temper at the point. Now fix a flattened ball of lead in the vice, the upper surface of which is so formed that the portion of the barrel that is to receive the hole for the post may rest securely. There is no necessity for the entire barrel to rest on the lead. Place a small piece of a mainspring, *q*, within the barrel against the circumference, where it will be maintained by the punch *p*, which will also hold the barrel steady on the lead block. Then give a moderate blow with a heavy hammer on the head of the punch, forcing its point through the barrel.

A burr will be produced outside the barrel while there will be a corresponding depression within, especially in front of the hole. To secure clean edges, pass a file over the external projection, but only sufficiently to remove its crest, and, resting the inside of the barrel on a lead block, drive inwards the metal that projects; then pass the punch through in a direction opposite to the first and of course with less force. Remove the burrs and repeat the operation first on one side and then on the other with gentle blows of the hammer, removing the punch by hand. Finish with a very fine file, which will entirely remove any external burr round the hole, and one cut with a slide-rest cutter in the inside, followed by charcoal and oil.

A watchmaker that has never performed this operation will do well to experiment with the punch on a small plate of brass, or, still better, on a worn-out barrel.

To insert the post, coil up the mainspring in the winder so as to be able to introduce a slightly conical piece of steel or brass between the two last turns of the spring and near to the

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hole. Place the post in position and hold it and the spring while the wedge that keeps the coils apart is removed. If the opening thus secured was found to be insufficient it might be increased by introducing a screwdriver, which is held down until the post is inserted. The making of this curb, shown at *b*, fig. 5, plate X., will offer no difficulty.

564. Stopwork.—If the pitch circles of the finger-piece and star-wheel of several Geneva stops be measured, it will be seen that three different proportions may exist (fig. 12, plate VIII.), in which the former is less than, equal to, and greater than the latter respectively.

When the finger-piece has a greater diameter, as at *d*, it will oppose an increased resistance to the hand in winding, but the direction of its pressure against the stop will be much below the centre of rotation of the star-wheel, because the finger is necessarily very short.

When the finger-piece is very small, as at *a*, there will be less resistance opposed owing to any want of freedom of the star-wheel, and the pressure against the stop will be more nearly tangential, the finger being relatively long; but more care will be required in the construction and, for a given force applied to the key in winding, there will be a proportionately increased pressure against the star-wheel axis.

Inconveniences thus increase in proportion as either piece is enlarged as compared with the other, and the best proportion is secured by making the two diameters equal, as shown at *c b*.

The stud on which the star-wheel rotates should be cut square, or, preferably, slightly conical downwards.

565. To true a star-wheel.—The form of a star-wheel can be adjusted on the mandril (**414**); on the tool shown in fig. 18, plate VI. (**377**), using a cylindrical mill-cutter and adding a stop so that the branches of the tool are always brought to the same distance apart; and, lastly, in the ordinary turns by using the little tool for making wheel-

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cutters, fig. 19, plate VIII. (**465**). The cutter employed should be cylindrical, the star-wheel being fixed by a conical-headed screw at the top of the support *k* N, which should be provided with an index at the side to enter each notch of the wheel in succession, and thus determine its position under the cutter.

Star-wheels can be bought of the material-dealers, but they are not always equally divided; indeed, some exist that have been merely punched in the punching press. Hence it follows that many of them are characterized by at least one of the following faults : teeth of unequal length or with their concavities of unequal form.

When the teeth are well formed and finished at their ends, but of unequal length, this arises from the star-wheel having been badly centred during the operation of cutting ; it must then be re-centred. Take a small brass plate H, fig. 1, plate IX., and drill a hole at its centre, with a notch at the edge, *a*, to receive the convex tooth without shake. Now place the plate in the mandril and turn out a sink to receive the star-wheel and hold it firmly. The convex tooth will then drop into the notch and the wheel should project a little above the face of the plate. Now release one dog, and, having gripped with it one tooth of the wheel, take a fine-pointed graver and true the central hole and the sink that receives the screw-head, taking care only to remove a small quantity of metal at a time.

If the workman has not considerable experience in using the mandril and fears a derangement in releasing and again tightening the dog, he had better remove the plate, cement the star-wheel in position and replace it, when it can be re-centred with the pump-centre.

566. To make a finger-piece.—After having drifted the square hole in the centre of a steel disc of suitable dimensions (see articles **367—8** and **713**), and traced out a line to mark the circumference of the disc and the end of the finger, drill two holes a little beyond this line, leaving such a

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space between them as to ensure that the base of the finger shall possess sufficient strength; but these holes should be drilled so far in towards the centre of the disc that freedom is left for the corners of the star-wheel teeth during its rotation. The head of the finger is at first left so as to exactly fit the spaces of the wheel without play, this being subsequently given with a fine file and in the smoothing.

File the circumference all round so as just not to touch the line traced out; then, putting the disc on an arbor, hold a fine *barrette* file against the edge, and cause the arbor to oscillate backwards and forwards with a bow, the file coming in contact alternately with each side of the finger. This smoothing of the rim will materially facilitate and abridge the final work with the graver. Care is necessary in the use of the bow while applying the graver; it must be strong but steadily handled, the graver very carefully sharpened and only a little metal removed at a time; first using the point and then the edge to smooth the rim. The corner of the rim on one side of the finger having been finished off with the graver edge, reverse the arbor between its centres to treat the other corner in a similar manner. A finger-piece made as here explained will be found to be very true.

Some watchmakers, when it is possible, finish the circumference after it has been adjusted on the barrel-arbor itself; but as a rule this is not necessary.

The slit that receives the pin may be cut as follows:—File a square piece of brass to fit the hole in the finger-piece, cut a notch across the end with a screw-head file, and insert it in the square hole. Having centred a flat cutter, the thickness of which is equal to that of the slit to be cut, on a taper arbor, place this between the runners of the lathe; resting the brass horizontally on the T-rest (which had better be at the back of the lathe, so that the progress of the operation may be more easily observed), present the notch to the cutter, and one or two strokes of the bow will make a

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slit of the requisite depth. The cutter can be easily made by one of the methods explained in article **464,** &c.

567. It will be understood that the foregoing details relate to the method to be adopted in making the finger-piece by hand, but it is very easy to arrange an addition to the ordinary turns, with or without a throw, for rounding or trueing the circumference with great rapidity.

Having mounted a circular mill-cutter on an arbor between the runners or on a chuck, as seen at R, fig. 1, plate X., replace the T-rest by an upright that has a shoulder, and is truly cylindrical, and of a diameter to fit the support without shake; the finger-piece, D, is fixed to its upper end by a cone and nut, as in the screw-arbor, or by any other means. A lever *l* is adapted to the vertical rod, so that it can be rotated between two stops on the lathe-bed; such stops are, however, not always needed, because by employing a thick cutter that is smooth on the face there is no danger of damage to the finger. At the same time, if there are no stops, considerable care is requisite in the smoothing and polishing to prevent the sides of the lap touching the finger. This can be polished afterwards in a very short time by using a lap that has been turned on the edge to fit the notch. It is useless to enter into further particulars, as the little appliance or one of an analogous description can be easily made.

The apparatus shown in fig. 6, plate VIII., and described in article **459** could be employed for such a purpose.

568. To make a clock barrel.—*Old method.*—A strip of soft brass, thicker than the circumference of the drum is intended to be, is coiled into a circle rather less in diameter than the required barrel, on a cylinder of hard wood, either by pressure between the jaws of a vice or with a mallet or hammer. The two edges, after being carefully cleaned, are soldered with silver solder or brazed, while they are held in position by a piece of binding wire wound round the drum.

Placing this ring on the nose of a beak-iron, harden it by

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gentle blows, so as not only to harden the brass, but also to increase the diameter and make a true cylinder.

Chuck it on a cylinder of hard wood (**290, 403**) in order to turn the two ends square, and form the edge that is received in a groove cut in the bottom of the barrel; the bottom is then (soft) soldered in position. In the older barrels that contained very strong springs, it was often the practice to leave tongues projecting round the drum that entered holes in the bottom and were riveted on the other side.

The barrel may be cemented to a large wax chuck that has at its centre a short arbor tapped and provided with a washer and nut, or it may be gripped by its base in the dogs of a mandril, and the surfaces, &c., finished.

Some of the details given in regard to a watch barrel are applicable here.

New method.—The drum is now no longer made by bending a strip of brass, because brass tubing is always to be obtained at metal warehouses which only needs to be cut into rings of the requisite length.

569. To make a barrel-arbor.—This can be done twice as fast in a lathe driven by a wheel as when the bow is employed.

If the metal is in the rough and has the scale on, it must be cleaned either on the stone or with acid (**81**).

The following method of procedure has been proved in practice to be expeditious:—

When the arbor has been turned to shape with the graver, smoothed, and almost polished, it is placed in the barrel and should rotate when in position, but with considerable friction. Then make the two squares as explained below (**571**); and, after smoothing that which receives th finger-piece, set this latter in position on the arbor and see that it does not descend quite to the shoulder. Then replace it by a worn out finger-piece, or by a copper disc that is cut so as to allow of the insertion of the pin in exactly the same

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position as is required by the finger-piece to be definitively used. It is then easy to drill the pin-hole from either side of the square and to smooth it with a fine broach. Each time that the arbor has to be inserted in the barrel, great care must be taken to remove any burr, as it might damage the barrel-holes.

Before hardening the arbor, cut in it two grooves of moderate depth at the points at which the ends must be broken off. Such a practice has two advantages: (1) the two waste points of the arbor can be removed and each end partly formed without employing a file, an arrangement whereby it is possible to maintain in the arbor a maximum of hardness, at least at the winding end; and (2), if the arbor is distorted, it will not be in the body, but from the points at which these cuts are made. And if any distortion occurs, the blowpipe jet can be directed on the points, which are then removed with a file before the final polishing.

570. To harden the arbor, place it in an iron tube and surround it with animal black which is pressed down, having previously been well dried. When the whole has been heated to the requisite temperature, throw it into water, and, if the precautions already explained under Hardening (**87**) are adopted, the arbor will be found to be smooth and clean and without either scales or blisters on its surface. Clean and polish it; this latter operation will give the proper freedom to the pivots, although it often happens that a touch with a broach is required in the two holes.

The bevelled groove within the ratchet teeth is polished by rotating the arbor while a small steel plate, perforated at its centre and of the form shown in plan and section at z, fig. 14, plate VIII., is held by the hand against the groove. The shoulders can be easily and rapidly polished in the tool represented in fig. 18, plate VI., and described in article **377.** (See also **580.**)

571. To make the squares.—To make drifts.—The tool shown in fig. 14, plate VIII., is used. On the plate P,

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which is at right angles to the foot S, is fixed a frame that carries two hard steel rollers, *c* and *d*, the edges of which are extended to form a guide.

A bent finger *b* is hinged on a screw on the side of the plate, and has a hole *j* drilled in it, which is continued for a short distance into the plate P.

The following is the method of using the appliance :—

Fix to the arbor a disc, indicated by dotted lines, in the circumference of which are four equidistant notches to receive the nose of the finger *b*. The rod S takes the place of the T-rest, and the arbor is placed between the runners of the turns. As S can be raised or lowered to any position and the runners can be moved laterally, it is easy to bring the point at which the square should commence to correspond with the line *n n*. The finger *b* having been inserted in one of the notches of the division-plate, reduce the arbor with the file L. Move *b* to the next notch, and repeat the operation, and so on with the other two sides.

If there is any danger of the finger not maintaining a sufficiently firm hold of the plate, a tight fitting pin can be inserted in the hole *j*.

At first the arbor should be filed away less than is actually required, and the only adjustment necessary to ensure this is the raising of S to a suitable height. No difficulty need be experienced in this, but, if any doubt is entertained, a screw may be supported from the bed of the lathe, terminating in a rod that passes through the plate P, as indicated at *t* for example, thus securing perfect regularity in the upward and downward motion of the system.

Details in regard to the method to be adopted in making a square by hand will be found in articles **711—2.**

If a tapered square is required, it will be sufficient to slightly incline the frame by means of two screws *v*, *i*, placed near its left-hand edge with their ends resting on the plate P. Such conditions principally arise in the making of drifts **(367, 713—4).**

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572. To drill exactly through the centre of the arbor.—Of course if the old arbor-nut is available, it will afford the best guide for performing this operation, and, if the arbor is tapped, such a hole will not be required. But when neither of these conditions is satisfied, the workman will have two slight difficulties to overcome: the drilling of the arbor and its nut exactly in the centre and parallel to the plane of the ratchet. By adopting the following method, he can easily satisfy these conditions:—

573. Take a brass disc D, fig. 9, plate IX., turned smooth on its two faces. Enlarge its central hole until the barrel-arbor enters it to such a distance that a blow of a mallet will drive it up against the ratchet where it should hold firmly. This disc is chucked on the wheel-cutting engine, and a groove is formed that passes exactly through the centre, using a hinged cutter-frame, or advancing the frame by a screw. Ascertain by means of a douzième or a thickness gauge whether the thickness of the disc, measuring from the bottom of the groove to the under side, is equal to the space between the shoulder of the arbor that corresponds to the outside edge of the barrel hole, and the point at which the hole should be drilled. If the thickness is excessive, diminish it from the under side; if, on the other hand, it is not sufficient, fit some thin discs on the arbor, and then force the brass disc to the position thus determined upon. It is hardly necessary to add that when this is done, holes must be drilled to some depth on either side of the arbor, using a drill that does not shake about in the groove, although quite free and inclining slightly downwards so that the hole shall not be above the point determined upon, namely the bottom of the groove. Continue the drilling until the two holes meet, the drill being maintained, during this part of the operation, parallel to the face of the ratchet.

574. If the workman is not provided with a tool for cutting the groove exactly in the axis of the disc, the

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accuracy that is so essential can be ensured as follows:—A brass rod G, fig. 9, plate IX., is divided into four at the end as near the centre as possible by means of a fine saw or a file that only cuts with its edge, which will be used to form the groove. Set the rod G in the turns, a centre of the form *f* being inserted at *b* where the slits cross, and turn down the rod G *b*, although only a little metal should need to be removed, until it enters the hole in the brass disc and projects a short distance on the other side. It then only remains to insert in one of the notches of G *b* the cutting file or the saw previously used, to form a groove on the surface of the disc that passes exactly through its centre; it is to be carefully remembered that the saw, &c., must only cut with its edge, and should enter the notch with a very slight friction, sufficient to indicate that it fits without play.

575. The arbor nut.—*Its diameter.*—This has been fully discussed in the *Treatise on Modern Horology*, to page 667 of which the reader is referred. The usual practice is to make the diameter of the nut equal to one-third that of the inside of the barrel. With thick springs of but slight flexibility it must be larger so as to avoid over-straining the innermost coil, and, conversely, with a very thin spring it is diminished, rendering the employment of a longer spring possible. When the nut is too small the spring must be made long, and, by setting up the stopwork, a coil of the spring can be maintained always on the nut.

576. *To drill the nut along a diameter.*—By means of the rod G, fig. 9, plate IX. (see article **574**), draw a straight line to indicate a diameter of the nut. This line will serve as a guide for marking two points opposite to one another on the circumference, round which a circle has previously been traced with a graver; one such point is seen at *n* (fig. 10, plate IX.). The points should be marked so deeply as to ensure that the drill does not displace itself in the initial stages of the drilling; with a little caution, and using a glass, very little difficulty will be experienced in ensuring that the

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points are in a right line. One of the two following methods may then be employed for drilling the nut:—

(1.) Prepare a brass block of the form shown at $f\ p\ f^1$, fig. 10, plate IX., the space A being cut away, and the end p provided with large-headed screws shown at v, v, in the plan. The two faces f, f^1, must be parallel to each other, and at right angles with the face p, a condition which can be easily satisfied by means of the mandril; the face f^1, for example, being turned towards the headstock, and the dogs introduced into the space A; the opposite face f is then trued with the slide-rest. If a mandril is not available, drill two holes in the direction indicated by the dotted lines $f\ f^1$, and turn the two external faces flat in a pair of turns. In the vertical face $a\ a$ make a round hole through which a pointed centre passes, being pressed forward by a spiral or other spring, and the point corresponding exactly with the line $a\ a$ traced on the face of the brass; of course the axis of this centre must be at right angles to the same line. A small block may be inserted within the space A to prevent any flexure of the arms.

An inspection of the figure will make clear the manner in which this little tool is to be used. Having fixed the nut on the face p by the screws v v, so that the two points on its circumference coincide with the line $a\ a$, the whole is placed in the drilling tool with the dogs pressing either on the upper external face or in the space A. After the block is fixed, ascertain by rotating the uprighting spindle that its point coincides in all positions with the top mark on the edge of the nut, and drill as usual. Drill one side, invert the block and proceed in a similar manner to drill the other.

The mandril can be used for this operation, the drill being centred in a runner or in the manner explained in article **413.**

The little appliance above described might be simplified by being made of the form shown at E, fig. 10, plate IX., which would require to be reversed when the second hole is about to be drilled.

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577. (2.) After tracing the circle round the nut, and marking the points in the manner already explained, some watchmakers fix it in a screw-ferrule and, supporting one of the points by a runner of the turns, present the drill, which is supported on the T-rest, against the other point, and rotate the nut by a bow passing round the ferrule: in fact, by a process exactly similar to that adopted in replacing a broken pivot (**256, 352**).

One objection to this method is that a ferrule must be used that is very large as compared with the size of the object operated on, especially if it cannot be held in the rim of the ferrule. It would be better to use a ferrule the centre of which has been entirely cut away, as shown at A, fig. 11, plate IX., or merely with a slot in it, as B. The nut would in such a case be cemented in position.

578. To polish the inclined faces of ratchet teeth.—*First method.*—Set the ratchet in rotation by means of a hand or foot-wheel, and bring a strip of spring covered with coarse rouge and oil against it from the side, resting the strip on the T-rest. In a very short time the teeth will be rounded and polished. This process is similar to that adopted at the present day for polishing the inclines of cylinder escape wheels in the lathe, which has been explained in the *Treatise* at page 291. The position of the polishing spring and its inclination must be determined upon by trial, so as to make sure that the entire surface of the tooth is acted on.

579. *Second method.*—Make a small boxwood lap, and arrange it as shown at M, fig. 14, plate IX., so that, when caused to revolve on its axis, which may be more or less inclined, it is brought into contact with the ratchet wheel with its axis as indicated by the figure. The teeth will cut into the wood, and trace out a helix as seen at M^1, and the lap, passing successively into the ratchet teeth, will cause it to revolve rapidly. When the groove is deep enough apply some coarse polishing rouge to the surface of the

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drum; after a few rotations the faces will be found to be polished.

The arbor and lap may be arranged in either of two ways.

Mount the lap between the centres that carry the cutter in a wheel-cutting engine and support the barrel-arbor opposite to it in a vertical direction between the chuck and the bent arm or "gallows" used to fix a wheel while cutting its teeth. Or a pinion engine would be preferable, as it is evidently better adapted for the purpose.

A watchmaker who is not provided with either of these tools must chuck the lap in a lathe of some kind that is driven by a wheel, then mount the barrel-arbor in such a carrier as is shown at *p p*, fig. 14, plate IX., and, resting its base on the T-rest, hold the ratchet against the lap, determining the most suitable height and inclination by trial; this, he will find, can be easily done.

580. To polish the circular groove in the ratchet.—It takes a long time to accomplish this by using first an iron polisher with oilstone dust, then one of copper with rouge and oil. The operation can be performed more expeditiously by using an iron runner as shown at B, fig. 14, plate IX. The end is rounded to correspond with the groove; and the hole, which is indicated by dotted lines, should be large and funnel-shaped, so as to avoid contact with the corners of the winding square when a see-saw motion is given to B in the polishing.

The arbor being cemented to a chuck in a lathe that is driven by a wheel, hold the end *o*, charged with oil-stone-dust or rouge, in the groove, and, while the arbor revolves, rotate the spindle B in the hand, at the same time giving it a see-saw motion as above mentioned. A very little practice will be required to do this.

If not provided with a hand or foot-wheel, mount a ferrule on the arbor, and, after placing the bow in position, support the point *s* either in a runner or at the side of the vice and press the spindle against the groove with one hand while the

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other works the bow ; the operation is precisely similar to the facing of pinions, except that in that case the end of B must be square (article **609**). (See also **570.**)

581. Repairing a barrel-arbor.—*To renew the ratchet.*—Cement the arbor *a a*, fig. 18, plate VIII., to the lathe chuck or mount it in a fusee-arbor in the ordinary turns. Turn down the ratchet, removing its teeth and thus diminishing its diameter by about a third, as shown at *n n* ; then reduce the thickness to a half, turning it down on the side next to the winding square, and continue this square down to the flat disc that remains, taking care that no shoulder is left at the angle between the two. The arbor is now in a condition to receive the new ratchet which has to be fitted.

Adjust a flat ratchet *r r* like those used on the barrel-arbor of a fusee watch, which must be of the thickness and diameter of the original ratchet, so that it exactly fits the winding square ; turn a sink in it, as shown by the dotted line, to receive the disc already formed ; and, if the hole fits the winding square freely but without play, and this square is carried down to the disc, the dust cap *c c* will maintain the ratchet in its position as effectually as though it formed one with the arbor.

By adopting the above method, which does not occupy much time, it is often possible to avoid making a new arbor when all but the ratchet is sound ; and if this portion should again wear out, the necessary repair is still further simplified.

We are assured that arbors repaired in the above manner showed no signs of wear after fifteen years, except that the square in the ratchet was a trifle enlarged, though not sufficiently to interfere in any way with the efficiency; moreover, in modern watches, the winding square is generally long, so that the ratchet can be left somewhat thicker at the centre and a corresponding sink cut in the under side of the dust cap to receive it.

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582. To true a barrel-arbor that is coned inwards or too large.—Cement the arbor firmly to a chuck as shown at C, fig. 2, plate IX. With care it will be easy to make the part *e* run true. As a rule but very little metal requires to be removed to make *e* cylindrical or conical in any desired direction, and it will generally be sufficient to finish by polishing with an iron polisher and oilstone-dust or coarse rouge and oil. Use a narrow polisher that only bears on the end of *e*, giving it a double movement, straight forward and in a half circle towards one side; or else use a broader polisher, supporting it on the T-rest. By inclining this the iron can be prevented from touching *e*, except near its extremity. It is unnecessary to add that when the arbor has been made cylindrical or coned in a given direction a suitable polisher bearing on the entire length of *e* can be used.

Either of the two following methods can be adopted in place of that above explained :—

Support the winding square end of the barrel-arbor in an excentric runner and let the opposite end run in a small coned hole in the end of a steel runner which must be polished and hardened so as to prevent the corners of the square that receives the stop-finger from wearing it away; now apply coarse rouge until the fault no longer exists and follow with fine rouge to complete the polishing.

If not provided with an excentric runner, it will be sufficient to take a tight-fitting key, drive it on with a blow of a hammer and file a point at the tapped end so as to be in the axis of the barrel-arbor. Having attached a ferrule to this key, place the whole between the runners and proceed as explained above.

583. To renew a worn winding square.—The best plan is to make an entirely new arbor; but when this cannot be done, as, for example, on the ground of expense, the following method of repair may be attempted :—

Direct the blowpipe flame on to the square while holding the body of the arbor in a pair of pliers, so as to prevent its

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being over-heated; and round off the corners of the square, leaving the diameter no greater than is necessary for strength, and tap it with a screw-plate. Now drill a hole at the end of a piece of round steel of somewhat greater diameter than the original square, and form an internal screw by means of a tap made in the same hole of the screw-plate as was used for the arbor; the end of the tap should be tapered and with good cutting edges.

If the arbor is the full length allowed by the case, reduce the length slightly and screw on the small steel spindle, tapped to the right depth. It must not be screwed quite down to the ratchet, although intended ultimately to come into actual contact. After having thus tested it, form the square (in the manner explained in article **571** or **711—2**), which will naturally be rather larger than the original, and cut a deep groove with the graver at the point where the square is to be broken off, but, before breaking it, harden and let down to a blue or violet temper; then smooth, polish, and screw finally on to the arbor. If this last operation does not result in the square breaking away, grip the spindle in a vice and, taking the square in a pair of long-nosed pliers, break it with a sharp blow. It only remains to finish off the end in a screw-head tool.

584. Hollow barrel-arbor.—When very flat watches were fashionable, so little room was allowed for the winding square that it became necessary to make the arbors hollow; in other words, they were traversed throughout their entire length by a square hole into which the key, a square spindle, was introduced in winding up the watch.

At the present day such arbors are not made: indeed, it is seldom that such watches are met with, but this class of work has received a novel application in the set-hand pinions of keyless work. It is advisable, therefore, that watchmakers at a distance from the centres of manufacture should know how to make such a piece if occasion arise; the operation only involves one difficulty of any moment, and

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articles **713—4** on "drifting" explain how this may be overcome.

THE MAINSPRING.

585. A free and uniform action of the mainspring is one of the primary conditions that have to be satisfied for ensuring a continuously good rate. We have discussed this subject very fully in the *Treatise on Modern Horology*, and must refer the reader to it.

In reference to the blueing of mainsprings, see article **95.**

586. *To make the eye in a mainspring.*—Every watchmaker knows that this is commonly done by means of a mainspring punch; but in its absence a hole can be made by hammering a pointed punch one or more times through the end of the spring after it has been softened, and, after filing away the projecting metal, the hole is broached out or enlarged with the point of a graver and finished with a rat-tail file, taking care that the corners are rounded off so as to avoid the risk of cracks.

587. *To reduce the height of a mainspring.*—This and the following method are only to be resorted to when a new spring cannot be obtained.

Introduce the spring into a barrel of less height than itself and wear the steel away by rubbing it on a hard surface charged with oilstone-dust, keeping it constantly rotated between the fingers. When the reduction is sufficient remove the spring and draw-file it, so as to round off the two edges: then clean the entire surface.

588. *To unite a broken mainspring.*—This can be done by softening the two ends and riveting them together; but it nearly always happens that one piece rises above the other and constrains it. A better plan is to join the ends as follows:—

Let *d* and *a*, fig. 7, plate XIII., be the two pieces of a mainspring, broken at *a*. Make an opening, *b d*, at the end of one, and cut the end of the other piece as shown at *a r*,

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the width of the narrow portion between *a* and *r* being the same as that of the opening *b d*. Then introduce *a* sideways into *b d*, and the pieces will take the form shown at T.

589. *Selecting a mainspring: Adapting it to a fusee.*—The spring that is characterized by the most uniform uncoiling and the least difference between the force exerted when fully and only partially wound up will generally secure the most constant rate. In selecting one for a going-barrel watch or in adapting to a fusee, the adjusting rod, shown in fig. 9, plate XII., and described in article **592**, is used.

THE FUSEE.

590. The most simple forms of tool available for cutting a fusee are described in articles **451—3**, and the general system adopted in screw-cutting lathes is explained in the same place. With the help of these details any watchmaker will be in a position to arrange a fusee engine for himself or to use those that are to be bought. It only remains, then, to explain how the form of the fusee should be ascertained.

At the outset, however, we would state the three characteristic properties of a fusee that have led to its adoption and retention in high-class watches and marine chronometers: (1) it equalizes the motive force; (2) it enables us to use a *tapered* mainspring, in which the uncoiling takes place in the most advantageous manner possible; and (3) it secures a longer period of going.

591. To trace the form of a fusee.—Having ascertained the distance between the plates, mark off the height, *x y*, of the coned portion of the fusee, fig. 7, plate XII., that is to say, of the portion on which the chain is to be coiled, on a smooth brass plate. The base of the cone of which *x z* is a radius is traversed by the axis A B at right angles. Divide *x y* into four equal parts (as there are four turns) and draw the parallel lines 3, 5, 7. Now mount the barrel with its spring and arbor, either apart or held between the plates,

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in such a position that, when the lever *c b d*, fig. 8, plate XII., is attached to its square by the clamp *a b*, this lever can be rotated in a vertical plane, the spring being wound up by the operation: before the spring is brought into action, the adjusting weight *c* must be placed in such a position that the lever rests horizontal. Charge the pan *p* with weights until the lever is maintained in equilibrium with the spring wound up one complete turn, and note the weights added. Wind up the spring through two turns and again add weights until equilibrium is produced, noting the total weights added, and so on. When the operation is concluded there will generally be five weights. The radii of the fusee will be inversely as these weights, and it is easy to determine by a simple proportion (**9**), and taking the radius *x z* as unity, what are the radii *c* 3, *d* 5, *g* 7, B 9. Through the points 9, 7, 5, 3, *x*, thus obtained, draw a curve, which will give the form of the fusee.

When it is cut nearly to the required depth in the manner already explained, the uniformity in the motive force must be tested throughout the acting length of the mainspring: if necessary, the template on the fusee engine must be modified in accordance with the result of this experiment: the last cut is then given to the thread of the fusee.

If more points on the curve are desired so as to obtain a greater degree of accuracy, the mainspring must be gradually set up, not by turning the lever, which is commonly known as an *adjusting rod*, but by turning the barrel itself.

592. To adjust a fusee to its mainspring.—Set the barrel and fusee in position in the frame, with the mainspring and chain carefully hooked in their places, and the former set up about half a turn, and grip the fusee square in the clamp, *d n* of the adjusting rod shown in figure 9, plate XII.; then wind up the mainspring by rotating this lever with the hand until arrested by the stopwork. Now slide the weight *m*, which is held by friction and a light spring, along the rod until a point is reached at which the lever just neutralizes

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the force of the mainspring, so that the whole rests in equilibrium when left to itself. Rotate the rod backwards by half turns at a time. If equilibrium is maintained to the end, the fusee is well adjusted. But, when this is not the case, it will be found that the weight of the lever is too great or too small ; showing that the radius of the fusee is either too small or too great. Adjust the lever so that it balances with the radius of the fusee which is thus shown to be most deficient, and at all other points along the thread of the fusee more metal must be removed to an extent indicated by the experiment.

When not provided with a fusee engine, it is a common practice to use the ordinary turns and an equalling file smoothed on its two faces ; or a template might be adapted to the T-rest of such turns.

If the irregularity observed is but slight, it is advisable not to touch the fusee ; because, in the great majority of cases, an equipoise can be arrived at by altering the degree to which the spring is set up. Thus, if the weight is too heavy for the lower coils of the spring, set it up more, so as to increase its tension : in the converse case, of course, it must be let down. By trying several springs, especially if they are of different manufacture, it will very often be found possible to secure a sufficient degree of uniformity without there being any occasion to re-cut the fusee.

CHAIN.

593. To ease a chain.—When the links are rusty or not sufficiently supple, the chain should be placed in oil and left there for some hours at least. Round off the edge of a box-wood block, cut a groove across this edge and clamp the block in a vice : then place the chain like a saddle in the groove, so that it hangs down on either side. Applying oil liberally to the wood, take an end of the chain in each

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hand and pull it backwards and forwards in the groove, renewing the supply of oil at intervals. When perfectly flexible, the chain must be cleaned with benzine, or, after soaping, wash it in water and leave for some minutes in alcohol. After being dried, it is dipped in fine oil and dried in a clean linen rag free from fluff, pressing the rag against the edge. A chain treated in this manner will be found to remain supple for a long time, and it will not be liable to rust.

594. Riveting a hook, &c.—When riveting either a hook or link to a chain, it is very necessary that the end of the rivet be cut or filed quite square; for, otherwise, the blow of the hammer will bend the rivet, so that the chain will not be square on the barrel, neither will the riveting be firm.

WHEELS.

595. To rough out a wheel.—The sheet brass having been prepared in the manner indicated in article **103,** one face is smoothed with a file followed by oilstone-dust; the plate is then set up in the lathe or mandril, to true the other face with the slide-rest. On the smoothed face trace out the rim and the crossings. These latter can best be marked out on the dividing-plate or *grammaire,* already explained in article **372.**

After drilling the small holes *a, c,* &c., fig. 5, plate VIII., at the corners, cement the wheel to a plate that is perforated to permit the use of the pump-centre, and remove the metal between the crossings by first turning the sinks indicated by the shaded disc *s* with the slide-rest, and subsequently cut the groove *i i.* Now centre the wheel in the mandril and trace the arcs *a c* with a fine graver, moving the face-plate backwards and forwards in the manner referred to in article **416.**

Remove the wheel from the plate and finish off the spaces

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with a file. Two files will be needed for forming the angles: one a flat barrette file with the corner bevelled off and smoothed to nearly a right angle to go against the rim of the wheel; and the other a taper file with faces of the same curvature as the inside of the rim, its two edges being inclined at rather more than a right angle and smoothed carefully. If these simple precautions are not taken, there is a risk of cutting through the arms or making them too narrow.

Many of the details in the following article, although specially relating to a balance, will be found applicable to the construction of other wheels.

596. To make a plain balance.—The round plate of which the balance is to be made must be hammered with the greatest possible care and of a thickness but little greater than that of the finished balance (**103**). Smooth one face and cement it either to a perforated plate through which the pump-centre can reach the balance (if the mandril is to be used), or on the chuck of an ordinary lathe, or on the wax-chuck C, fig. 1, plate X. Hollow the middle portion with the slide-rest cutter or hook tool, according to the kind of lathe used; but, whichever it be, it must be very well set and only remove a small portion at a time. The application of an excessive pressure will produce a kind of rolling action which will induce a tendency in the arms to bend. Remove the metal between the rim and boss until its thickness is diminished by about a third; smooth this surface carefully, finishing with a piece of charcoal. The disc is now ready for crossing out.

Place it on the dividing-plate (see article **372**) to mark out the three arms, and remove the metal between them, either in the mandril, as explained above, or by drilling a series of holes parallel to the arms and rim. These holes should be so arranged that they can be enlarged with a fine-pointed graver (while the balance rests upon a flat wooden block or is cemented to it), and a turn with a sharp-edged

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broach, or the passage of a thin rat-tail file should be sufficient to separate the useless metal. As a rule the series of holes is drilled with the disc held against a wooden block, but the burrs produced on the under side by the drill prevent it from being maintained flat, unless they are removed after each hole is drilled, and this might occasion a distortion of the disc. It would perhaps be better to cement the rough balance to a sheet of zinc : the colour of the shavings would suffice to indicate whether the hole was through.

The arms and rim must be made smooth and even with nicely formed crossing files, the edges of which are smoothed to the most convenient angle as already indicated.

In filing the crossings the balance should rest against a small block in the vice, and they are rounded while resting in a groove at the edge of a similar block, specially shaped for the purpose. This block is also useful as a support in finishing the angles between crossings and rim.

The under face of the balance is smoothed with oilstone-dust ; and the arms by drawing the polisher along them while the balance rests on a flat block ; it is then cleaned and fitted on a very true arbor, as A, fig. 1, plate X. This should pass through the centre-hole of the balance without play after a broach has slightly enlarged it, and the balance is clamped by a cap and three screws, *j*. It only remains to set the arbor in the turns and polish the rim, first turning it to a half-oval if desired. In the latter case the rim, after being smoothed, is polished first with coarse rouge on hard pith, and subsequently with fine rouge on softer pith.

597. If the arms of a balance are found to be too long so that they curve, the rim must be lengthened by hammering with the greatest possible care ; the inside and outside of it must then be trued on an arbor of the form A.

The boss at the centre will be found thicker than is desirable ; its height can be reduced with the balance merely adjusted on a smooth taper arbor, but it is necessary to

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observe that the balance and arbor must not be adjusted to each other by pressing or by rotating the balance with the rim held in the fingers. It must be pushed on or off the arbor by applying pressure at the centre of the boss on one side or the other with a piece of hard wood resting firmly against the T-rest, while a rather strong bow causes the arbor to rotate.

Instead of the form of arbor shown at A, a screw arbor might be used with its cone pressing against a cap, but the balance must always be carefully adjusted on the arbor, and this latter must run perfectly true.

598. To make a compensation balance.—This balance requires the most minute care in its construction, and no point must be neglected. We have, therefore, entered into very full detail in regard to it in the *Treatise on Modern Horology*, to pages 741—4 of which we must refer the reader.

599. To make a number of identical wheels.—If it is desired to make a number of brass wheels of the same size and shape, the workman will find it much to his advantage to employ the punching machine, a tool that is daily coming into more general use throughout all the branches of the watchmaking trade. By adopting the following method he can make his own punches and bed-plates.

With a view to secure some length in the matrices that are used for forming the crossings, without augmenting the difficulty of construction, proceed thus: Each of the pieces V, V, (fig. 13, plate X.) consists of two parts:—(1) The star-piece *a c b d*, of three, four, five, or six arms according to the number of crossings of the wheel; and (2) the collar, V. The star-piece is of the same length as the collar, and is made in the wheel-cutting engine in the same manner as the leaves of a pinion. The punches, of which one is shown at P, are fitted by hand to the recesses of the star-piece, and then cemented in position; the whole is then chucked in the lathe and turned as one piece, so that its

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diameter is slightly greater than the interior of the collar. Now harden the star-piece and temper it to a blue colour. When cold harden the collar v *v*, and temper it to the same degree, but, while expanded by the heat in tempering, introduce the cold star-piece and drive it home. By proceeding in this manner, no subsequent hand-fitting will be required. v *n* must not be hardened.

Tools for punching the crossings of wheels are sometimes made on this system in which the disc of brass is fixed to a support that can be made to revolve by quarters of a revolution at a time, and a single punch serves to remove the metal by four separate operations. But as a rule it is better to use four punches together.

600. To repair wheels.—When the teeth of a wheel are damaged, the only possible remedy is to provide a new one. If, however, a single tooth is broken, the following method can be adopted, on an emergency, for inserting a new one:—

601. *To insert a new tooth in a wheel.*—Cut a small notch in the rim of the wheel, shown at *a*, fig. 7, plate XI., which should be dovetailed if possible, and the two sides spread out slightly from the upper towards the under side, as indicated at *c c*. Cut a small piece of well-hammered brass, of the form B, so that the part *d d* fits exactly into the notch in the rim. Now invert the wheel and grip it near to *a* in a pair of long-nosed pliers, which must be held in the vice. Moisten the inner faces of the notch with soldering fluid (**135**), and, placing B in position, put particles of solder round its edge; holding the lamp beneath the nose of the pliers, the solder will presently melt, and a drop of the fluid should be added to facilitate its running into the joint. Cool the wheel and wash thoroughly, first with water and subsequently with alcohol.

It only remains to file both faces smooth and level with the rim of the wheel; then shape the tooth carefully.

By introducing B from the side opposite to that which is visible in the watch, and sloping the faces *d, d*, to a less

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degree than *a*, the inverted wheel will present a recess to receive the solder; so that, on looking at the upper surface, at which the edges fit very closely, the joint will be scarcely visible.

Some workmen prefer to previously tin the edges (see article **137**), and not to present B to *a* until both are sufficiently heated.

602. *To true a wheel.*—When the teeth are found to be in good condition, but the wheel does not run true, or one or more of its arms are strained, the fault can be corrected, in a case of absolute necessity, as follows:—

Remove the pinion from its wheel. Enlarge the central hole in the lathe or mandril, and rivet or solder in it a brass ring that is slightly thicker than the wheel, and perforated with a smaller hole than that required for the riveting. Now centre the wheel from its circumference (**409—411**); increase the central hole with the slide-rest cutter, and turn down the two faces of the ring level with the wheel. Rivet the pinion in its place, after testing the truth of its riveting neck, when the wheel should be found to turn both true and flat.

If the wheel under repair is likely to be subjected to much force, at least two small notches should be left in the enlarged hole in the wheel to receive corresponding projections in the brass ring.

603. If the *crossings of a wheel are broken* and the wheel cannot be replaced, it must be chucked in the lathe and the arms turned out with a graver, the inner edge of the rim being at the same time turned circular, and a step turned on this edge where the metal is to be left of half its original thickness.

Take another wheel of the same size and thickness, or a plain disc, and turn it of the same diameter as the outer ridge of the step; reduce its thickness at the edge by one-half and a disc will thus be obtained with a ridge round the edge corresponding exactly with that of the wheel, and the

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one will fit in the other. They are, of course, soldered in this position, care being taken to prevent the solder from reaching the teeth, and the old wheel will thus be provided with a new interior.

If the disc is made to fit closely on the upper side, a wedge-shaped ring being left to receive the solder in the manner explained in article **600**, the joint will be scarcely perceptible on the exposed face, even with a glass.

In repairing delicate wheels in any way it is a good precaution to cement the rim to the edge of a hole in a brass plate, so that only the arms or other part to be operated upon is exposed.

604. To make a keyless winding wheel.—We will suppose that the old wheel is available as a pattern ; if it is not, the several dimensions must be ascertained by calculation in accordance with the laws of depths explained in the *Treatise on Modern Horology*.

The wheel may be roughed out in a pair of turns, using straight and hooked gravers ; but the operation is tedious and difficult. It is better to use an ordinary lathe, proceeding in the manner explained for making a compensation balance at page 741 of the *Treatise*.

If a mandril is accessible, prepare a thick plate, and drill a central hole, fitting a steel pin into it as shown at *o d*, fig 3, plate XIII. The diameter of *d* must be exactly the same as that of the pump-centre. Fit the wheel-blank R to the pin *o* without play, and cement it to the plate. Remove the pump-centre and insert *d* in its place, clamping the plate P firmly against the face-plate by the dogs. By using well-sharpened gravers or cutters, the wheel may be rapidly shaped (**297, 396**).

The pin might be forced in from the under side to the level of that face of the plate ; and if it were perforated as shown by the dotted lines, it might be centred by means of the pump. Or the plate P might be made circular and centred from its circumference.

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605. To cut the teeth on the circumference the wheel need only be fixed on the chuck of the wheel-cutting engine as usual by means of the steel cone. The crown teeth are cut while the wheel is firmly cemented to a pin-chuck like that used in turning it.

Other keyless wheels can be made on the same principle, and such modifications as may be necessary experience will suggest. Sufficient information in regard to wheel-cutting has already been given in **454** and following articles.

PINIONS.

606. To make a pinion.—At the present day pinions of all sizes can be obtained of the material dealers, so that it is very seldom that a watchmaker is obliged to make one for himself.

In an emergency, however, he can adopt the following method for making one out of the ordinary drawn steel; but it should be added that, in all probability, some practice will be needed before success is arrived at. Cut a length of steel wire of suitable diameter about two-thirds as long as the files that are to be used for shaping the teeth. Turn it down to form the axis, leaving a block near each end equal in length to the required pinion, as if two pinions were to be made on the same staff. Then cut and round leaves on both, keeping the file always in contact with a leaf of each pinion. By proceeding thus the sides and roundings of the leaves will be maintained parallel to the axis, and there will be no risk of the pinion being barrel-shaped, as is nearly always the case when a short pinion is held in the fingers or rested on a block in the vice.

Proceed in the same manner in smoothing and polishing, using pieces of some close-grained wood, such as walnut.

It is much easier to make the pinion of the required form by means of a revolving cutter in the lathe, if the workman

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is not provided with a special tool for the purpose: the arrangement of the lathe is described in article **459.**

In some factories the leaves are cut in two operations: a cutter with plain fine saw teeth divides the circumference into the requisite number of equal parts, the leaves being subsequently made of the correct shape by a special cutter, the method of making which has already been very fully explained in articles **474—491.**

607. To determine the size of a pinion.—The following table is usually employed for this purpose, and has been already given in the *Treatise on Modern Horology,* to pages 619—640 of which we would refer the reader for detailed information on this important subject. (See also **627** and the following articles of the present work.)

To give the approximate diameter to a pinion, the pinion calliper should include :—

For	16	leaves,	6 full teeth; that is to say, measuring the distance between the two external faces;
,,	15	,,	rather less than 6 teeth, or 5 teeth, and just beyond the point of the sixth;
,,	14	,,	6 teeth, measuring at the points;
,,	12	,,	5 teeth, measuring at the points (or rather 4½ teeth); for a clock-wheel, 5 full teeth;
,,	10	,,	4 full teeth; for a clock-wheel, 4 *squared* teeth;
,,	9	,,	rather less than 4 full teeth or 3 full teeth to the point of the fourth;
,,	8	,,	4 teeth, measured at the points, minus a quarter of a space;
,,	7	,,	rather less than 3 full teeth; for a clock-wheel, 3 full teeth, plus a quarter of a space;
,,	6	,,	3 teeth, measured at the points, or rather more; for a clock-wheel, 3 full teeth.

It is important to notice that these measures can only be regarded as a first approximation, and it is only by actual trial in a depth-tool that we can be certain that a pinion is

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correctly sized. By taking the measures in a micrometer or other accurately divided gauge provided with a vernier, the work of selecting will be much abridged; but how long will it be before the generality of watchmakers will make use of these convenient appliances? The well-known wheel and pinion sector, although convenient, is not equal to them in point of accuracy, and is affected by an error in measuring a chord, not a true diameter of the wheel or pinion.

608. To increase or decrease a pinion.—This subject has been considered in the *Treatise* at page 625, where it is shown that the pitch circle of a pinion may be increased by reducing the thickness of the leaves in such a manner that their flat faces are continued further on to the rounding; conversely, a pinion may be decreased by carrying this rounding farther down towards the base of the leaf.

609. To decrease a pinion without removing the wheel.—Some watchmakers recommend that the wheel be removed from the pinion, and, after the necessary reduction has been effected and the leaves re-polished, again riveted on the pinion-neck. Very few workmen, however, can do this well, so that after the operation the wheel is seldom found to run true. If a new pinion cannot be procured, the old one must be reduced in the manner described at page 641 of the *Treatise*, to which the reader must be referred. We would only add that the tool shown in fig. 18, plate VI., and described in article **377** can be used for this purpose.

When a pinion that is too large is replaced by one that is smaller, it is necessary to take care that the hole in the wheel is well centred and not too large; in either of these cases it must be enlarged and bushed after being centred by the circumference (see articles **409** and **624**).

610. To face a pinion.—Every watchmaker knows that a pinion is smoothed and faced by means of a polisher formed as shown at A, fig. 4, plate XIII., with a hole in the centre, and held in one hand, while the bow causing the pinion to revolve is worked by the other hand. The

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figure is sufficiently clear to dispense with any further explanation.

Some workmen, instead of using the runner-shaped polisher, use the swing-tool described in article **374**, and shown in fig. 14, plate VI.; but the best results are secured by the system explained in article **376** (see also article **580**).

611. To polish pinion-leaves mechanically.—It was formerly the custom to polish the leaves of a pinion, holding it on a block or between two fingers and traversing a strip of metal with oilstone-dust backwards and forwards in each space for the smoothing, and a similar strip of walnut-wood (with rouge) for polishing.

This method has long been abandoned in factories where all pinions are polished in a machine.

We will proceed to explain a simple arrangement for polishing pinions in the ordinary turns, but it is advisable first to describe one form of tool that is actually in use on the large scale for this purpose. The two only differ in their dimensions.

612. *Pinion-polishing machine.*—A frame B B, fig. 5, plate XIII., supports at its upper end an H-shaped piece, of the same form as the cutter-holder in an ordinary wheel-cutting engine; but the arbor, instead of carrying a cutter, is provided with a wooden drum R. On the base of the frame is a plate P, which can be fixed by the screw E, and carries a second plate *p* to serve as a bed for the slide, which supports the pinion to be polished freely between two brackets *a*, *a*. The plate *p* can be set a little oblique and clamped by the screw *v*.

The machine acts as follows:—Present a corner of a pinion-leaf to the circumference of R (which is caused to revolve by a cord passing round the pulley *n n*), the axis of the pinion being not quite at right angles with that of the drum, in order that the groove formed in the soft wood may resemble the thread of a screw, and so cause the pinion

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to revolve. When the groove is of sufficient depth, apply rouge if operating on a small pinion, and emery for a large one: after a few turns of R, the slide carrying the pinion being at the same time moved backwards and forwards, the pinion will be found to be polished. A better surface can be obtained by using flour emery.

The steel wheels of keyless work can be polished in the same manner. (See **579.**)

13. The spindle of the screw E passes through a rectangular slot in B in order that the slide and its support can be moved parallel to the axis of R.

The grain of the wood must be at right angles to the axis of rotation of the drum, and a wood that is non-fibrous is preferable. It must evidently not be too hard, and, if too soft, the thread formed on its circumference will get rough, and often will suddenly change position. When the entire surface has been worn it must be re-turned smooth and cylindrical. The larger a roller is, the quicker it will polish and the less it will wear. Moreover, it will render a proportionately less amount of motion of the slide necessary. The root of the walnut tree is specially sought after, but, when this cannot be obtained, lime-tree is recommended; other woods can, however, be used.

In factories where clock pinions are made, thin discs are employed in place of the drums. They are at least a decimetre (4 inches) in diameter, and very narrow at the edge, and can be re-turned when worn with a graver without being removed from the tool, if a T-rest be fixed in some convenient position.

The screw *d* is for limiting the descent of the drum, but some workmen prefer to dispense with it, and, instead, hold the frame C C in the hand, pressing it gently against the pinion. They urge that the wood is never of the same degree of hardness round its circumference, and therefore must of necessity wear irregularly; by holding C C in the hand the pressure on the pinion can be more evenly

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adjusted, as it is possible to feel at once whether the drum is polishing or scratching.

The inclination of the slide to a plane at right angles to the axis of R is measured by the pitch of the screw formed on the drum. But in practice no special precautions are taken, and it is only necessary to incline the slide slightly to the right or left, until the pinion is found to revolve freely.

The drum may be from 2 to 3 inches in diameter, and, in order to ensure the same degree of hardness throughout the entire circumference, it is a good plan to make the drum of a series of wedges cut so that the grain in all radiates from the centre. Beautiful polished surfaces are obtained in this manner.

614. *To polish a pinion in the ordinary turns.*—Various methods may be adopted, but the following is one of the commonest :—

Support the pinion between the two centres *b*, *d*, of the pinion-carrier shown in fig. 6, plate XIII., the form of which will be evident without explanation. Rest this carrier by the portion M against the T-rest, pressing it against the drum at the same time with one finger. Rotating the drum first by hand, make the pinion cut a groove varying the inclination until it is found to be correct, and, when sufficiently deep, charge with polishing material, and rotate it with a bow, at the same time moving the pinion-carrier backwards and forwards endwise. A little experience will give the requisite skill.

If the pinion is not held at a sufficient inclination it will scrape and will not revolve. If too much inclined, only the roundings of the leaves will be polished, the sides being left untouched. A well-formed groove will last for a long time.

615. To tighten a cannon-pinion.—If it is simply slack it will be sufficient to increase the diameter of the set-hands arbor by using the tool described in article **363.** But if the cannon-pinion is in the habit of working off this

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arbor when setting the hands, the arbor can be tapered a little downwards ; or proceed as follows :—

Drill a hole in the square that receives the minute-hand in the position shown at *a*, fig. 8, plate X., and also indicated by dotted lines at *c s* ; now turn a groove round the arbor, also shown by dotted lines, at the point *n*, to correspond with the hole *a*. Insert a pin in this hole, filing it off smooth with the surface at the side at which it enters, and nearly level at the other side, to be hammered over just sufficiently to prevent the pin from working its way out. The cannon-pinion will now be found to turn with the requisite degree of friction, and without any tendency to work up. It will last all the longer if both the pin and the groove in which it works are polished.

SET-HANDS SQUARE.

616. To make a set-hands nut.—This is a small square nut pinned to the pivot of a solid cannon-pinion that projects beyond the top-plate in some watches after passing through a hollow centre pinion ; this construction has been latterly discontinued, but it may be well to explain the mode in which such a nut can be renewed when necessary.

Take a rod of soft steel of a diameter half as large again as that of the square to be made. Drill a hole along its axis rather less in diameter than the set-hands arbor and cut off the end a little longer than the square is required to be. Put this nut on an arbor and turn it flat on each end (although still a little long) and truly cylindrical. Having inserted a loose fitting coned brass wire of oval section into the nut, hold it on its side on an anvil. With a sharp blow of the hammer cause the cylinder to assume an oval form, so that the round hole is as seen at A, fig. 5, plate X., this being the section of the end of the set-hands arbor itself. If the work has been carefully performed up to this point, the steel nut should now pass a short distance on to the arbor on applying

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a moderate pressure, and it will suffice to slightly alter the form of this latter in order to ensure a perfect fit. As there should be no shake it is advisable that this adjustment be made after the nut is hardened.

File the two faces *d* and *f* parallel to each other and to the axis of the oval, reducing the total thickness very nearly to the amount ultimately required; then holding the nut in the pincers by these two faces firmly, but without scratching them (or it may be held by a rod fitted to the oval hole), form the square, removing all the metal that is beyond the two vertical lines in the figure. Then set it on an oval arbor and turn the corners down to the exact diameter required; pass the graver over the two ends so as to adjust the length. It will then be easy to finish off the square and round the lower end, holding the nut on a steel rod in a pin-vice, in the manner explained in article **711** or **712.** Drill the hole for a pin after marking its two ends on the nut as explained in article **576,** then, holding the nut so that it rests on its lower face, form a recess with a chamfering tool held in its axis; the form of this can be modified if required with the rounded end of a rod and oilstone-dust.

Harden the square and temper it to a blue colour; then smooth its faces and ends, and fit the square to the set-hands arbor. The hole for the pin must now be made through this arbor, taking care not to allow the square to rise out of its place during the operation. It only remains to polish the recess formed in the nut with a rod rounded at one end and rotated with a ferrule, and finish off the corners with a burnisher and rouge; the lower end is finished in the same manner as the head of a screw.

617. We have here considered the case of a new arbor, but, if fitting a nut to one that is already drilled, proceed as follows: Make the nut rather longer than necessary and drill a hole higher than the point at which measurement shows it ought to be; then remove metal from the lower face until the two holes coincide. The work is simplified if

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the nut be made of the correct height at once and, instead of drilling a hole, a slit be formed as in the head of a screw, the bottom of which must correspond with the lower edge of the hole in the arbor.

618. To fit the set-hands arbor to the centre or cannon-pinion.—We have pointed out in article **364**, the objections to hammering the set-hands arbor so as to secure sufficient friction to make it hold in either of the pinions through which it passes in the ordinary form of watch. Tracing a spiral line on its surface is not much better as the metal thus caused to project soon wears off. A better method is explained in article **364**, but, when only a slight increase of diameter is needed, the following will suffice :—

Roll the arbor on a hard flat wood surface with a file of medium cut, applying considerable pressure so that the arbor is forced against the file. If the pressure is sufficient and maintained long enough, a dead rough surface will be formed on it which will increase its diameter so that it will retain a small quantity of oil. It is well to roughen the surface rather more than necessary, subsequently passing a burnisher lightly over it until the arbor fits the pinion with sufficient friction.

As to the making of a set-hands arbor, it will present no difficulty to a watchmaker of even average skill in turning and filing. For a method of forming the square mechanically see article **571**, and the precautions to be observed in making it by hand are given in articles **711—2**.

PIVOTS.

619. The play of pivots.—It may be accepted as an approximate rule that the play of escapement pivots in their holes should be as follows :—

In the cylinder escapement, about one-sixth the diameter of pivot.

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In the duplex escapement, about one-tenth the diameter of pivot.

In the lever escapement, about one-eighth the diameter of pivot.

A large hole causes the pitching of the depths to vary with position, and a deficient play renders the escapement more sensitive to thickening of the oil. This subject has been very fully discussed in the *Treatise on Modern Horology*, and the general conclusion arrived at is that the inconveniences when the play is somewhat in excess are less than when it is deficient.

The depth of a pivot-hole or the length of its cylindrical acting surface may be taken to vary inversely with its hardness. Thus a ruby hole is made less deep than one of brass.

620. To replace a pivot.—Full details have been already given in regard to this subject, in articles **351—2.** The reader is also referred to the details given in regard to the drilling of hard steel in articles **328—333.**

621. To replace the pivot of a hollow pinion.—It often happens that the pivot of a hollow centre pinion is so deeply cut that it cannot be re-polished, in consequence of the careless manner in which too many examiners finish the centre holes (**518**). If the pinion itself is found to be still in good condition, it can be made serviceable as follows:—

Cement the pinion, with its wheel attached, firmly to the chuck of a lathe after having removed the two worn pivots, and, when it is accurately centred, increase the hole by means of a drill that is a trifle larger than the original pivots (see article **328**); in the hole thus enlarged and carefully smoothed insert a close-fitting steel tube that has been hardened and tempered to a blue colour, which must be smoothed and run true. The portion of this tube that projects on either side is then adjusted to the proper length, and it only remains to polish the pivots.

If only one pivot requires renewal, ascertain whether there

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would be sufficient hold with the hole enlarged through half its length, and proceed as already explained.

We have assumed that the shoulders of the original pivots can be made to serve again, but it often happens that the shoulders do not possess sufficient substance, in consequence of the hollows being cut too deep. In such a case, it is hardly necessary to observe that the hole must be drilled larger, so that, after the tube has been adjusted, new shoulders can be turned on it.

622. To redress a bent pivot.—For this purpose some workmen merely use a pair of pliers or tweezers; others place the pivot in a slot of the Jacot tool, and press on it with a burnisher that has little or no cut, at the same time causing the staff to rotate. Either of the two following methods may be adopted:—

Drill a number of straight holes in a plate exactly at right angles to its surface. Now introduce the pivot into a hole that it fits with very little play, and redress it by causing the staff to rotate, at the same time holding the plate in the hand. Caution is necessary since there is some risk of bending the pivot too far.

Or the arbor may be placed between two cone-plate runners (**255**) in the turns, H and B, fig. 4, plate XIII., a collar C having been first fitted to B that can be fixed in any position by a screw, and has a projecting arm *d*, forked as shown at d^1. A small adjustable guide *i*, fitted to this fork, serves to alter the depth of the space d^1. Clamping the axis of the wheel between the two runners so as to prevent its rotation, with the bent pivot inclined from the letter B in the figure, place on the pivot a drilled punch, of brass or steel, with its stem passing freely into the space d^1. Then pressing this punch downwards to the stop, the pivot will be straightened, and it only requires that a burnisher be passed over it.

If there is any fear of the wheel moving it should be held between the fingers. The end *p* of the punch must pass

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rather below the horizontal plane in order to ensure that the pivot is straightened.

The accidental breakage of the pivot may be guarded against, if this is thought necessary, by first fixing a ferrule to the end *p* of the punch in order to increase its weight; then direct a blowpipe jet against the point *o* and, when the pivot is let down to a blue colour, the weight of the punch will bend it into a horizontal line.

623. Pivoting a cylinder, &c.—This operation will not present any difficulty if the several heights are properly taken, a subject on which full instructions are given at pages 269—272 of the *Treatise*. See also the articles on Beaupuy files (**240**), and on compasses for measuring heights, &c. (**243**).

624. Polishing pivots in the lathe.—Pivots are as a rule polished by metal polishers provided with suitable materials, and held in the hand; in fig. 9, plate VIII., however, is given the design of a machine by which this work can be accomplished when the pivoting is done in the chuck-lathe, the pivot itself being free and unsupported by a runner.

The bed P of the instrument carries a wheel R which engages with a pinion on the axis of the polishing lap *m*. The wheel R is mounted on a clock stud passing through a slot and fixed by a nut, so that the pitching of the two mobiles may be modified; motion is communicated to the lap by simply placing the finger against the teeth of R. The bed can move in a vertical plane, being pivoted on two screws *v*, *v*, and the block that receives the points of these is riveted to the disc *d d*, which can be made to rotate, with friction, on the second disc *n n*. This latter is riveted to a plate *e* fixed at the end of a cylindrical rod F.

It will be evident that if the rod F is inserted in the T-rest support, the plate P extending towards the back of the lathe, this plate can be raised or lowered, and moved towards the right and left, so that the flat face of the lap

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can always be brought in contact with the pivot that is to be polished. This latter is caused to rotate by a foot-wheel while one hand holds the raised plate by the button *a*, and a finger of the other hand is applied to the teeth of R, causing the lap to rotate.

The upward motion of P may be limited by the edge of the top *s* of the button *s k*, which is tapped so as to rotate with stiff friction on the pillar H. The stop *l* is to prevent the polisher from travelling too far towards the left and thus removing too much from the shoulder that is to be polished. The screw *x*, giving motion to the slide *y* is for securing parallelism between the pivot and the surface of the lap, according as the former is cylindrical or conical.

For fine pivots it is advisable to introduce an additional wheel and pinion. The finger will then be better able to appreciate the degree of resistance opposed, and, owing to the increased velocity, it will be useless to use oilstone-dust, but rouge can be applied directly after the turning. At *e* is a steady-pin for maintaining the position of the instrument.

BUSHING PIVOT-HOLES, ETC.

625. Every watchmaker knows how to proceed in adjusting an ordinary perforated bouchon or stopping. We would make a few remarks on the subject of bouchons generally.

The tapped bouchon is very firm, but, in order that it may be well centred, it is essential that its thread fits exactly the tube of the tool (**347**), and that the pointed rod is exactly central. A turned bouchon, especially when a broach can be passed into it after it is in position, is more easily made central (see article **369**).

When bushing holes that are rather large with solid bouchons, after the hole has been marked with the pointer it must be drilled with a small drill, a larger one being

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subsequently passed through, so as to increase it. Otherwise there is great danger of the hole turning to one side.

If a hole, such as that of the centre-wheel, is bushed with a perforated bouchon, it will often be found to incline towards the barrel or fusee, so that the hole is displaced. Such an inconvenience may be avoided by using a bouchon with a hole smaller than is ultimately required, afterwards enlarging it with the plate centred (by the bar pivot-hole) in the mandril or lathe.

626. Riveting of bouchons.—Some watchmakers have found considerable advantage in replacing the sudden and irregular impacts of a hammer by gradual pressure, without shock, obtained by a small press worked by hand on the principle of a punching-machine. With a well-made bouchon, the flat end of which is slightly rounded and the inside of the hole in the plate finished with a rat-tail rather than with a cross-file, it is found that the riveting is always perfect. Others employ an ordinary pair of sliding tongs, the noses of which are drilled to receive two punches, one flat and the other rounded, as in the mainspring-punch. Three pairs of punches suffice for all sizes of bouchon, and the same tool can be used for closing up screw-holes, &c. (See **366.**)

627. Movable bouchons.—These are for use in regulator clocks and others of large dimensions, and a few words must suffice for their description. They are the invention of M. Alleaume, and will be understood from fig. 4, plate X. It is always desirable, with a view to prevent wear, that when metal pivot-holes are used, the pivot should bear on a length equal to about three times its diameter; but for such a condition to be satisfied, it is essential that the axes of both holes and pivots be absolutely parallel. The figure will at once show in what manner such parallelism is secured. C C is the plate, in section, in which a hole is made of the form indicated by the lines that bound the cross-hatchings. The movable bouchon A is held against a shoulder, and prevented from rotating by a screw, the point of which enters a small hole

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in the bouchon. The pivot of B passes into A, and this latter is capable of such slight motion as will ensure contact between the surfaces throughout their length.

DEPTHS.

628. To secure a good depth.—The least skilful of watchmakers can, without much difficulty, place a wheel in the depthing tool in conjunction with a pinion, and change this latter until the two are found to run easily together. But there are comparatively few that are sufficiently acquainted with the subject of depths to be able to select a pinion whose proportions are such as to satisfy the greatest number of the conditions to be fulfilled by a good depth.

This unsatisfactory state of things is due in great measure to the employment, without any correction, of tables of the sizes of pinions (**607**), according to which these sizes are determined by a measurement on the teeth of the wheel taken with a pinion calliper. This method, although sufficient for ascertaining the size approximately, and even for securing a depth that runs more or less easily, cannot be accepted as an unvarying rule.

Far from resting on any mathematical law, as ignorant men urge in their attempt to instruct others, it is only true for a particular number and form of tooth in regard to the wheel, and a definite thickness of leaf and shape of the rounding in regard to the pinion. It ceases to be true if applied to other numbers of teeth or to pinions that have their leaves thicker or thinner, or the roundings different from those of the pinion first determined upon.

All this subject has been very fully considered and explained in the *Treatise on Modern Horology;* and every watchmaker that is desirous of acquiring aptitude in the pitching of wheels and pinions should specially study the following articles of that work:—

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Causes of stoppage and variation occasioned by bad depths, 1150—3; *To practically examine a depth*, 1154—5; *Verification by Touch*, 1156—7 ; *To remove the causes of stoppage*, 1158—1160 ; *Contrate depths*, 1166.

See also articles **606—9** of the present work, on *Pinions*.

629. *Theoretical and practical depths.*—The fundamental principle of every depth is as follows :—To determine what curvature should be given to the teeth of the wheel which drives, in order that the tooth that follows (whether its side be straight or formed according to a pre-determined curve) shall be driven in such a manner as to secure the best transmission of force, a transmission which is in part influenced by the uses to be made of the machine.

630. Teeth formed like the involute of a circle (see *Treatise*, pp. 590 and 646) have very marked advantages, but they cannot be adopted in practice, especially in the case of the leaves of pinions. The epicycloid (*Treatise*, pp. 606 and 613) can be realized very approximately in the teeth of wheels in horology, and such teeth can be used in conjunction with pinion leaves having straight faces, the construction of which does not present any difficulty. This explains why the epicycloidal form has been adopted by watchmakers ; but, although it is more easily drawn than the majority of other curves, there are still some obstacles in the way of its general application, mainly dependent on industrial requirements. The difficulty is usually got over by forming the tooth according to a circular arc, nearly identical with the epicycloidal curve (see articles **497—9**).

631. When two mobiles are of the *same diameter*, the theoretical depth will be characterized by having teeth and spaces of equal width ; but, since in practice the friction with such an arrangement would be excessive, owing to its taking place on both sides of the tooth, the teeth of the wheel that is driven are so far reduced in thickness as to secure the necessary freedom.

632. When the two mobiles are very highly numbered,

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the lead is short, so that the tooth of the wheel may be a trifle broader or narrower than the space without inconvenience.

But when using pinions of low number (from 6 to 10 leaves), this is not the case. In proportion as the width of the wheel-tooth is reduced, its ogive becomes shorter, and the most advantageous portion of the lead (that beyond the line of centres) becomes less. And, besides this, account must be taken of the slipping towards the end of the lead, and the reduction in the difference between the geometrical and the total diameters of the wheel.

633. To secure a good depth with low-numbered pinions, the leaves should not be more than half the thickness of the space. If they are thicker than this, it may be found necessary to reduce the width of the wheel-teeth, when the pitching is insufficient; but the most serious objection lies in the fact that the pitch circle of the pinion will be diminished in diameter. Let there be two pinions with circular roundings and of the same total diameter, but having leaves of different thicknesses—that with the leaves thick will be found to be too small, &c.

634. To calculate the vibrations of a pendulum or balance.—Multiply together the numbers of teeth of the wheels, starting with the one that carries the minute-hand (which therefore makes one revolution in an hour), but exclude the escape-wheel.

Multiply together the numbers of leaves of the pinions, commencing with the one that engages with the centre-wheel.

If the first product be divided by the second, the number obtained gives the *number of revolutions* of the escape-wheel in an hour.

Multiply this figure by *twice the number* of teeth of the escape-wheel, and the product is the *number of single vibrations performed by the balance or pendulum in one hour.*

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ON THE APPLICATION OF THE GEOMETRICAL LAWS OF DEPTHS TO PRACTICE.

635. It has been urged that when the geometrical forms of the leaves and teeth, as given in scientific treatises, are accurately carried out in practice, the depths are found to be unsatisfactory and liable to cause occasional stoppage; and these facts are brought forward as evidence that theory and practice are at variance.

On the contrary, theory and practice are in perfect accord: the apparent disagreement arises from an error in the application of the geometrical laws.

In copying the theoretical forms of the teeth of wheels and leaves of pinions, it would be necessary to ascertain that they were mathematically exact, and this is impracticable. Two conditions must be borne in mind:—

(1.) Theory shows that the mobile which drives should be made a trifle larger than the geometrical size, so as to counteract imperfections in the workmanship (*Treatise*, p. 612).

(2.) A pinion is *never* made of the exact mathematical proportions, in consequence of the processes that have to be adopted for cutting, polishing, centring, &c. If a number of pinions be taken, and if the several dimensions of each be determined by means of a micrometer measuring to hundredths of a millimetre (or from two to three-thousandths of an inch), differences that are, comparatively speaking, large will be found in the diameters, measuring between corresponding leaves; in the thickness of leaves; in the diameters of the circles at which the roundings join the straight faces, and the general truth of the pinion will nearly always leave something to be desired. It should be added that these faults will be more marked according as the leaves have been more quickly made.

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The teeth of wheels will be found to be characterized by similar faults, although they are less marked.

636. It follows from these facts that, in watches and timepieces, the *pinion is always a little smaller* than theory would require; thus the epicycloid should be struck with a somewhat smaller generating circle, and the ogive of the tooth will be proportionately reduced.

The *practical conclusion* at which we arrive, then, is as follows:—As it is impossible to secure absolute perfection in the teeth of small horological mechanisms, their ogives must be slightly more rounded at the points than the designs given in scientific treatises indicate, since these latter are drawn exactly in accordance with the geometrical laws.

These remarks are of the greatest possible importance to the manufacturers of both watches and timepieces; they point to the fact that not only the ogives of all wheel teeth should be lower than theory indicates, but also that, in commoner work, they must be still lower, according as the pinions are of more inferior quality.

637. To alter a keyless winding pinion depth.*—The depth of the keyless winding wheel and pinion often occasions considerable inconvenience, and its adjustment requires to be accurately made: when the depth is too deep, its alteration is easy, as the roundings of the pinion leaves can be reduced, or the stud or other piece that carries the winding wheel can have its base a little reduced on one side, so as to set the wheel a trifle out of upright (but so slightly as not to be perceptible to the eye, and taking care that the teeth remain on a level with those of the barrel-arbor wheel). A shallow depth is somewhat more difficult to correct. If a sufficient change cannot be made by altering the support of the winding wheel, one of the following methods must be resorted to:—

* A. Philippe, *Les montres sans clefs*, p. 213.

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(1.) Reset the pendant of the case.

(2.) Make a new winding pinion of greater diameter, increasing the number of its leaves by one, to correspond to this change.

(3.) Alter the position of the movement in the case.

The two first methods are more especially applicable to new work, while the third is most convenient for jobbers, although of course it can only be resorted to with advantage when the pinion has a bearing in the pendant. The requisite change in the position of the movement can be produced by raising the rim of the case that supports the plate, or by soldering two thin strips of metal on this rim, producing a similar effect; one on either side of the pendant will suffice, except when a considerable change is necessary, in which case they should be set at intervals round the rim, to avoid an obvious inclination of the dial. Or four holes can be drilled at equal distances apart round the edge of the plate and in its plane, so that their edges overlap the position occupied by the rim of the case; pins are then set in these holes and filed away until they produce the requisite amount of elevation. Or, again, flat-headed screws may be fitted round the edge with their axes at right angles to the plane of the plate and their heads on the dial side.* The depth will then be adjusted by screwing these screws more or less into the plate.

It is advisable to ascertain that the dial is not forced too near the glass, as such is occasionally found to be the case, necessitating the bevelling of the edge of the former.

ESCAPEMENTS.

638. The consideration of the methods to be adopted

* It may be well to point out that the above details relate to the case in which the keyless work is on the top plate. When it is under the dial, of course the corrections here given for a deep and shallow depth will be reversed.

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in planning, making, adjusting, and correcting the various escapements used in watches, timepieces, and clocks would go far beyond the limits of the present work; for it is by no means sufficient to indicate, for example, how to make a cylinder or to cut a pair of pallets; the workman must be enabled to make or repair such pieces so that a good rate may be secured both at once and in the future. He must not only know how to recognize and avoid causes of stoppage and variation that are due to careless workmanship or bad proportions, &c., but also how to correct such faults when they exist. We can therefore but refer the reader to the *Treatise on Modern Horology* where everything relating to escapements, depths, motors, &c., is fully treated with an abundance of practical detail. Indeed, no other work exists that affords so large an amount of theoretical and practical instruction to the horologist. In evidence of this fact, it is sufficient to enumerate the following subjects :—

Construction of the under-mentioned escapements, with the causes of their stoppage and variation, and the methods by which they may be corrected :—

Verge escapement . .	pp. 54 to 93
Cylinder „ . .	„ 94 „ 296
Duplex „ . .	„ 297 „ 345
Lever „ . .	„ 353 „ 473
Detent „ . .	„ 474 „ 515
Timepiece escapements . .	„ 527 „ 559
Regulator clock „ . .	„ 560 „ 568
Turret „ „ . .	„ 569 „ 584

The remainder of the volume is devoted to such subjects as depths, motors, the pendulum and balance, balance-spring, springing and timing, compensation, &c.

It should further be added that the numerous practical details in regard to construction and repair are due to some of the most skilful and accomplished watchmakers.

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In the succeeding paragraphs a few practical details will be given that are not contained in the *Treatise*.

PALLETS.

639. In addition to the articles in the *Treatise* devoted to the consideration of the lever escapement, we would refer the reader to two lectures on the English Lever delivered by Curzon * where much information of a practical kind is given and several special tools are described (see article **642**).

640. To advance a (visible) jewel in a pallet.—Workmen that have had much experience of escapement making do this without any difficulty by holding the pallet arm in a pair of tweezers that has been slightly warmed, but ordinary jobbers will not succeed with such a method : they can, however, effect the required change as follows.

Make a small brass plate, E, fig. 8, plate IX., with a piece *c* projecting upwards, which the screw *v* traverses with stiff friction. A saddle *b* is fitted to the edge of the plate by screws. A glance at the figure will suffice to show the mode of using it ; the pallet arm whose jewel is to be adjusted is clamped under *b* with the jewel just opposite the screw *v*. Now turn this screw until it stands at the distance from the impulse face of *a* through which the jewel is to be advanced ; taking the plate in a pair of long-nosed pliers, hold them over a small lamp flame, and press with a small screwdriver lightly against the point *a*, so as to advance the stone by the requisite amount as soon as the shellac is sufficiently soft. A particle of shellac is now placed at *a*, if any cavity forms during the process, and the plate is laid on some cool body, avoiding contact with the pallet-staff.

If the stone projects below the lower surface of the pallets, a small washer must be placed underneath before clamping

* *Horological Journal*, Vol. XIX. (1876-7), pp. 85-92 ; and Vol. XXIII. (1880-1), pp. 114-116 and 125-133.

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the screws of *b*, of such a thickness that the stone is just on the level with the surface of E.

641. To alter the form of a pallet face.—Workmen that possess the requisite skill and steadiness of hand can alter the form of a pallet jewel, when it is necessary to modify the height or form of the impulse face, by simply using a copper polisher charged with diamond powder. The polishing material employed is always decanted in very pure

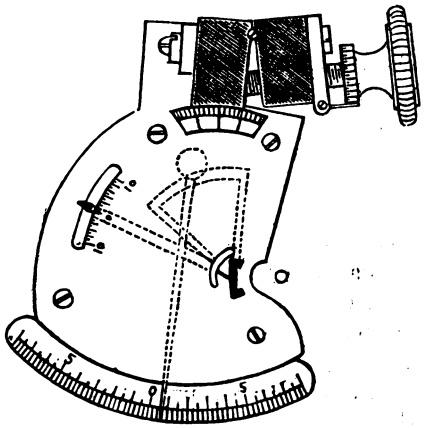

FIG. 23.

oil (see article **169**), as otherwise it is apt to scratch instead of polish. The least fine quality is first used when a material change has to be effected, but if only a very slight alteration is necessary, and the adjustment has to be very exact, only the finest quality must be used, as there is a danger of making scratches that would be very difficult to erase. We would only add that this operation requires some skill and patience.

For the method adopted in making a pallet-stone, see article **213.**

642. To measure the lift and all other angles, &c.,

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of the lever escapement.—A very complete instrument for measuring these angles was designed by Bridgman, and is described in the *Horological Journal.** Curzon has recently suggested† a simpler instrument which any watchmaker can arrange for himself, and is quite sufficient for all practical purposes. This is shown in figure 23, and consists of an ordinary depth tool to which a scale is added. A hand adapted to the pallet staff supported between one pair of runners of the depth tool gives motion to a curved rack (shown by dotted lines), and this causes a pinion carrying a second index to rotate, the radii being so related that the movement of the staff is magnified four times on a scale which can be observed while the glass is at the eye examining the pallets. The index which travels over the shorter scale to the left (divided up to 10° on either side of zero) is connected with the pallet-staff by a fork and a short arm passing through the circular groove; it affords a convenient means of moving the pallets while testing them, and gives a measure, in degrees, of their motion. The graduated arc shown at the top is for measuring the lever and roller.

The same authority describes several other gauges of special use in lever escapement making, for a description of which the reader must be referred to the lecture already quoted.

643. It may be convenient here to give references to various papers, &c., that have a bearing for the most part on the English lever watch, which may be consulted with advantage by the reader who is desirous of obtaining further information on this and cognate subjects.

Grossmann's Prize Essay on "The Detached Lever Escapement." Leipsic. 1866.

Scotchford's Essay on "The Lever Escapement." Reprinted in the *Horological Journal.* Vol. XXIV. (1881—2.)

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* *Horological Journal.* Vol. XVIII. (1876), p. 173.

† *Ibid.* Vol. XXIII. (1881), p. 114, 125.

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"Essays on the Compensation Balance." *Horological Journal.* Vol. XVII. (1874—5.)

Glasgow on "Making and applying Balance Springs." *Horological Journal.* Vol. XVII., 151, and XIX., 99.

J. F. Cole on "Isochronism and Elasticity of Metallic Springs." *Horological Journal.* Vol. XVIII.

"Bridgman's Tool for Measuring Lever Escapements." *Horological Journal.* Vol. XVIII., 173, and XIX., 104.

Bickley on "Watch Finishing." *Horological Journal.* Vol. XIX., 43.

Collier on "Watch Examining." *Horological Journal.* Vol. XIX., 113.

Curzon on "Lever Escapement Making." *Horological Journal.* Vol. XIX., 85; XXIII., 114, 125.

Ganney on "English Watch Repairing." *Horological Journal.* Vol. XXIII.

"To Calculate Conversions, Lever Trains, Motion Work, &c." *Britten's Watch and Clock Makers' Handbook.*

644. Verge pallets: to measure their opening.—The little instrument shown in fig. 13, plate XII., may be used for this purpose; its mode of action will be easily understood from an inspection of the figure.

One of the pallets being held with its flat face against the base of the graduated semicircle by the lever and spring B, so that the axis of the verge is at right angles to the plane of the instrument through the point *n*, an index previously fixed to the other pallet will show by the graduations the number of degrees of opening.

This index, shown at P, fig. 12, must be very light. It is formed in two parts, the body *c d*, and the small spring *z z*. The pallet when held in the notch *c*, must have its face held flat against *c d* by the spring *z z*. The face *c d* of the index must be quite smooth and straight, so as to avoid any error in the reading of the scale.

The pressure-block C, fig. 13 (shown in plan and elevation at C, fig. 15), is movable on its centre, and this centre, which by an engraver's error is represented on the line *n r*, should be a little to the right of that line.

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645. To open or close verge pallets.—Some workmen cut a notch at the end of a small rod in which the middle of the verge is inserted, the two arms of the fork being then drawn together by a screw; then, holding each pallet in a pair of long-nosed pliers, one in each hand, the rod is held in the flame of a lamp and, as soon as the body of the verge becomes blue, it is gently twisted to the right or left according as the pallets require to be opened or closed.

This method is not always convenient, and the following may be recommended:—

Support the verge by its shoulders between two cone-plate centres in a pair of finishing turns, as seen in fig. 15, plate XII. A carrier *b* is screwed to the upper pallet, and prevents the verge from rotating; *c* is a rod through which heat is conducted; *a*, shown both in plan and elevation, is another rod, which is much longer than *c*, and has a notch cut at the end, so that it can be forced on to the lower pallet. The end *d* is free, and the T-rest, shown dotted at *s*, must be brought nearly into contact with it, the distance between them corresponding to the angle through which it is required to alter the opening of the pallets. Now hold a lamp under the free end of *c* and, as soon as the body of the verge changes colour, *d* will descend by its own weight until arrested by *s*. The opening will thus be increased or diminished to the requisite extent.

The operation will be accomplished more quickly by directing the blowpipe flame against the verge body.

Of course when diminishing the opening, the verge must be held in the reverse direction to that shown in the figure.

CYLINDER.

646. The cylinder escapement has been discussed at very great length, both from a theoretical and practical point of view, in the *Treatise on Modern Horology*; we shall therefore

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only here describe a form of polishing lathe not there given, referring the reader to that work for all information on the subject.

647. To polish the cylinder lips mechanically.—The polishing of the lips of a cylinder is one of the most delicate operations that can be undertaken by a watchmaker; we have, therefore, endeavoured to devise an instrument by which this can be done mechanically, and which should at the same time be so simple and so easily made that any watchmaker should be able to construct it for himself. An examination of the cylinders ordinarily met with shows clearly that machines are used in factories; but not having seen any of these, we cannot say how far they resemble or differ from the one here described, and shown in fig. 1, plate XI.

648. It consists of two distinct parts which take their place in an ordinary pair of finishing turns. (1.) The plate P, supported on a rod T, to take the place of the T-rest; (2.) the frame E, whose axis replaces one of the runners. This much being clearly understood from the figure, there will be but little difficulty in understanding the following details.

On the plate P is mounted a bracket, *b b* b^1, held by a screw and washer. It has a slot cut lengthwise, so that on loosening the screw it can be made to slide towards the right or left. The vertical portion b^1 supports a fork-shaped piece, *d c*, a front view of which is given in fig. 2, pivoted on a collet-screw, *f*, and this may be fixed by a pin passing through its end like a bolt. The upper end of the fork-piece is provided with teeth for a purpose that will be presently apparent.

The long spindle, *g h*, turns between the two supports, *k*, *l*, fixed to the plate P, under the action of the handle M. This axis carries two excentric cams, *q* and R. When it rotates, the excentric R causes the fork *d c* to rise and fall, thus occasioning an oscillating movement of the rack *d*. At

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the same time the other excentric *q* presses against the back of the slide *i n*, which moves freely in the guide *s*, and is always held against the cam by a helical spring *j*; the slide thus has an oscillating motion in the direction of its length.

All the details in regard to the slide and its guide will be easily gathered from the plan in fig. 1, and the side elevation in fig. 3.

A small iron polisher is adapted to the slide *n i*. Being pivoted on a pin at one extremity, serving as an axis, its end *u* is pressed downwards by the light spring *v* (figs. 1 and 3), which might be replaced by a spiral spring below the polisher if preferred.

649. This being understood, we will pass to the frame E. The rod that carries it is formed of thick drawn steel pinion wire, the diameter of which is less than that of the hole in the poppet-head of the turns. This spindle is provided with brass collars at *y* and *z* of such an external diameter as to be received in the poppet-head, in which the rod can rotate freely. By adopting this arrangement, not only is the frictional surface diminished without reducing the accuracy of the adjustment, but the apparatus can be easily adapted to any pair of turns.

To the right-hand side of the frame is fixed, by two screws, the cylinder carrier *x*, shown apart at X., fig. 4. It must be removed in order to set the cylinder in position by cementing its balance to the surface; care is necessary to make sure that the back of the cylinder shall be towards the side *e* of the frame when the carrier is again screwed in position. After having thus replaced it, set the rack *d* to engage with the pinion wire at *z*, in such a manner that, when the excentric cam R occupies the position indicated in fig. 2, the small iron polisher rests at the middle point of the cylinder lip. Now finally clamp the screw that fixes the support T.

The mode of action of the machine will be easily understood. If, after charging the polisher with polishing rouge,

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the handle M is rotated, the cam R will impart an oscillating angular movement to the frame E through its axis *y z*, and the cam *q* will, at the same time, cause the polisher to move backwards and forwards, always in contact with the surface of the lip during its movement.

650. The work will be performed more rapidly, and the polish will be better if the iron have a slight lateral motion as well as that in the direction of its length. It is, however, more simple to communicate a longitudinal oscillating movement to the cylinder, and this answers the same purpose; it is only necessary to make two small additions, the spiral spring *o* and the little cock *a*. The latter is fixed to *d* in an inclined position (as indicated at A), and this inclination can be varied by merely turning the left-hand screw. It will be evident that when *d* is ascending the cock will push the spindle *y z* forward; and when *d* descends, this spindle will be brought back to its initial position by the pressure of the spring *o*, which is simply placed over the end of the opposite runner. This longitudinal movement must be but slight, and it can be made as little as desired since it depends solely on the inclination of *a*.

651. *Observations.*—(1) The angular motion of the frame E must be sufficient to enable the polisher to act on the entire surface of the lip. The extent of this movement is determined by the size and the degree of excentricity of the cam R. The greatest motion will occur when the spindle passes through the hole 1 (fig. 2), and it will gradually become less as the holes 2, 3, &c., are used. The cam *q* should also have two or three holes for varying its excentricity. These cams may be made of hard wood, ivory, &c.

(2.) The iron polisher may be replaced by a piece of flexible spring fixed by a screw to the slide; but its pressure is less uniform.

(3.) The bent arm *w*, figs. 1 and 4, is clamped to the plate P by a screw *d*, and the long arm *b* (fig. 4) bears against the back of the poppet-head, and thus ensures the

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steadiness of P. To ensure steadiness by its means, *b* is drawn back in the direction of the arrow, then hooked behind the poppet-head and clamped by the screw *d*. The firmer the support is the better.

(4.) The machine may be arranged so that the two lips can be polished at the same time, but it then becomes more complicated. In the tool here described, as soon as one lip is polished the cylinder carrier is unscrewed, turned round, and screwed against the left arm of the frame E, in which are two screw-holes opposite to those in the right-hand arm. Unscrewing the slide *b b*, the T-rest carrier is moved along the lathe bar until the polisher is over the lip ; *b b* having been set in position is clamped, and, after seeing that *w* has a bearing, the second lip may be polished.

(5.) The cylinder carrier shown at X, fig. 4, is used when the balance is in position. For a plain cylinder without its balance another form of carrier is employed that has at the edge of its central hole a small but solid projecting shell to which the cylinder is cemented.

652. *Methods of obtaining continuous motion.*—Rapid work is not possible when a simple handle, as shown at M, is used for working the apparatus ; recourse may, however, be had to one of the following methods :—

(1.) Mount a small pinion with a square hole at its centre, and make it engage with a large wheel driven by a handle. This wheel, having a greater number of teeth, will proportionately increase the rate of motion.

(2.) At *h* fix a ferrule that gives a continuous movement in one direction as described in article **320**, and drive it with a long bow.

(3.) Take a powerful clock movement and connect up its centre arbor with the axis *g h* ; having wound up the mainspring, allow it to run down as long as it possesses sufficient power to drive the mechanism.

(4.) Fix a ferrule at *h*, and drive it by the aid of a foot-wheel.

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653. Various small tools for holding escape-wheels while cleaning, testing the evenness of their division, &c., are described in articles **356—9** of part IV.

BALANCE.

654. The method of making a plain balance is explained in articles **596—7.** For full details in regard to the compensation balance, see pp. 741—4 of the *Treatise.* (See also **548**).

BALANCE-SPRING.

655. To make a balance-spring.—This is one of the most important pieces in a watch as influencing the uniformity in its rate. We would refer the reader to the articles on Springing and Timing in the *Treatise on Modern Horology,* where very full details are given in regard to the balance-spring, and where the methods of making those of both cylindrical and flat form are described. Some additional details are however given below (**663**).

656. To select a balance-spring.—Various methods are adopted for this purpose. The most common, by which the strength is ascertained from the length of cone formed by hanging the balance from the inner coil of the spring while the outer is held in a pair of tweezers, is described at page 222 of the *Treatise.* A more exact method, based on the same principle, is to employ the small gauge shown in fig. 24.

A vertical pillar *n n* is fixed on a smooth plate B, and the slide C is held by friction in any position on *n n.* Place C so that the distance between c^1 and B is equal to the distance between the end of the lower balance-staff pivot and the balance-spring collet. Having now fitted the spring in this collet, raise the balance, by tweezers holding the outer coil, until the lower pivot just rests on B. The graduations on C

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will then afford a measure of the extension of the spring, and this extension should about equal the radius of the balance measured on the same scale.

When the number of vibrations performed in an hour is known, we have shown at page 239 of the *Treatise* that a spring may be selected by fitting it to the balance and, while holding the outer coil in the tweezers, supporting the lower pivot on a hard smooth surface; the balance is then made to vibrate, and the vibrations are counted. The spring need

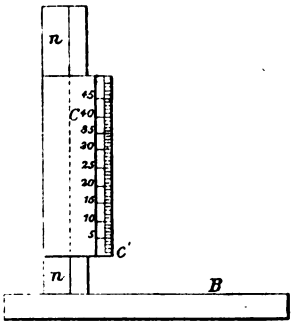

FIG. 24.

not be pinned into the collet, but may be attached by wax to the top pivot.

See also articles **539—543** on the rapid timing of a watch.

657. To fix a balance-spring to its collet. — A common way of doing this is to put the collet on a wire or broach which is held in one hand while the other presents the inner end of the spring, held in tweezers, to the hole in the collet; subsequently fixing it with the pin. The following is a more convenient method:—

At the middle of a brass plate is a boss tapped through a vertical hole in its centre to receive a small screw with flat head. When the collet is fixed by this screw passing

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through it, the operation of setting the spring in position and pinning it will be much facilitated, and the plate will at the same time afford a means of testing its parallelism. Two or three screws with heads of various sizes should be provided, and, in order that they may be always available, they should be screwed into holes at a corner of the plate.

This tool might be made of further use by adding an arrangement for holding the stud while drilling it, with a view to ensure that the hole is at the proper height.

658. Balance-spring gauge.—A back view and side elevation of this are shown in fig. 15, plate VII.; it can be made without difficulty by any watchmaker.

Through the middle of the plate passes a staff *a b* lightly pivoted between the cock *p* and the plate, and projecting on the left-hand side as far as the point *a*. Between the cock and plate it carries the collet of the spiral spring *s* and the stop-finger *d c*, and at the point *z* is a light finger *y z* that passes over the graduations on the dial.

When the stop-finger *d c* is free it stands in the direction of the dotted line *i*; on rotating the staff, by taking hold of the pivot *a*, in the direction of the arrow *i*, the extremity *c* of the finger will be brought round till it presses against the inclined plane *r*, which it will force back and, on coming against the stop near *c*, it will be held fast in the notch of the small bent lever that terminates at *r*. A spring maintains this lever always against a pin set in the plate. The index finger *y z* will now be standing over the zero of the scale, and will be maintained in that position until the finger *d c* is released by a momentary pressure of the hand on the push-piece *n*, when it will fly back to the initial position corresponding to the dotted line *i*.

659. The instrument is used as follows :—

The small sliding holder H, which is shown in section at E (both of these figures being much enlarged since it is extremely fine and light), has a hole through its centre that fits on to the axis at *a*. Having set a balance-spring

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in the clip as indicated at E, place H on the pivot *a*, tightening the slide so that it can be used to rotate *a b*, and bring the stop-finger round to the position *d c*. Holding the outer coil of the spring in tweezers at *v*, its inner coil being held in the clip, release the bent arm by means of the push-piece, *n*. The point on the dial at which the finger *y z* is arrested will give a measure of the force of the balance-spring *v*.

It will be evident that a spring can now be easily selected of the same strength as *v*, or stronger or weaker within definite limits which will become well known when some use has been made of the instrument.

The entire mechanism is enclosed within a box that is covered by a glass, through the middle of which a hole is made for the passage of *a*. The spring *s* is of about the strength ordinarily used for 18-line watches.

660. To set a Breguet spring in position.—To the the strength of a flat spiral spring that is to be formed into a Breguet spring, it must first be attached by its collet to the balance-staff. As the outer coil cannot be held in the stud owing to its being so near to the pivot-hole, it must be held in the clip *b* of the little appliance shown at S, fig. 15, plate VIII. Holding the watch-plate between *a* and *c*, the arm D can rise or fall on the rod *h*, and *b* can be brought to such a position that it grips the spring at a point just beyond the stud, so that, when the spring is turned inwards, the point held may be brought up to the stud. The springing of the watch can thus be proceeded with, and springs tried until one of the required strength is obtained. It then only remains to give the spring the double curvature, and to take care that the end of the overcoil is brought sufficiently near to the centre.

Since the action of a Breguet spring is more free than that of an ordinary flat spring, the watch may be found to lose slightly; it is advisable therefore to time the watch before making the bend, so as to show a gain. A little experience

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will enable the watchmaker to avoid being much out, and any trifling error that there may be is corrected either by a displacement of the bend or by altering the central coil. If the latter method is to be resorted to, it is better that the watch should lose rather than gain a little.

661. To flatten an ordinary balance-spring.—Remove the collet and stud, and clamp the spring by a central screw between two plates, which are then placed on a blueing tray and gently heated. A small piece of whitened steel is laid on the plate in order to see that the heat does not exceed what is needed to give a blue temper. Allow the plates to cool and separate them.

Ordinary springs, being made of rolled steel and subsequently coiled, always open out on heating; it is therefore necessary, before resorting to the above method, to coil up the spring, as otherwise the outer turn will be found to have opened beyond the stud.

662. To diminish the strength of a balance-spring.—Scraping the end or the entire length always renders the spring defective. Dipping in acid is very little better. It is preferable to imbed the spring in cork or soft pith, and work it over a ground-glass plate covered with oilstone-dust that is fine and smooth. This method might be resorted to for reducing the height of a mainspring.

If the cork or pith is hard and only a little metal has to be removed, the operation is successful; but it is apt to result in more metal being removed from the edges than from the centre. When much has to be removed, the spring must be cemented to the polishing plate (shown at G, fig. 17, plate VI., and described in article **378**) with fine wax, thoroughly liquid, so that on pressing the spring all its coils may come in contact with the plate; it must be held thus until cold. Now adjust the levelling screws, so that the whole surface bears flat on the glass; rub it as long as is considered necessary, and detach the spring as soon as the plate is sufficiently heated; boil in alcohol to clean its surface.

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663. Polishing the coils of a flat balance-spring.—After a spring has been made and hardened as explained at page 772 of the *Treatise on Modern Horology*, Glasgow recommends the following method of polishing their coils in a valuable practical paper on this subject :—*

Take a piece of wood or large pith coned at one end and having a pin projecting about half an inch from the apex of

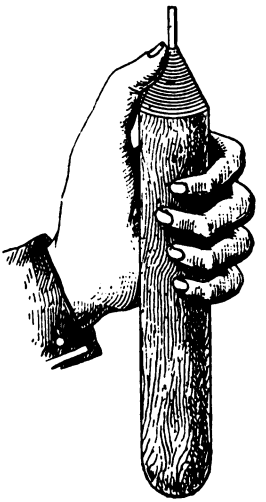

FIG. 25.

this cone, as seen in fig. 25; putting the spring over this pin, draw its outer coil down by the thumb of the left hand, and with a well-worn brush charged with red-stuff polish the outer coils, turning the spring when one side is done to repeat the process on the other. The inner sides are more difficult to polish. If the spring be placed on a piece of flat cork and a finely-cut peg be inserted as shown

* *Horological Journal.* Vol. XVII. (1874—5), p. 151.

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in fig. 26, and pressed firmly on the cork, the spring will take a conical form, and by moving the peg (supplied with red-stuff) backwards and forwards and also in a lateral direction, the inside will soon be polished; but great care must be taken not to bend the spring during this process, as it would thereby be spoilt. The flat edges are polished on writing-paper rubbed over with red-stuff in the manner explained above for reducing the strength of a spring. Wash it in benzine and the spring is ready for blueing.

664. Rozé balance-spring.—Fig. 7, plate XIV., was added in the French edition of this work as explanatory of

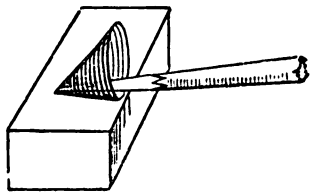

FIG. 26.

paragraph 1377 in the *Treatise on Modern Horology*. It is therefore unnecessary to again consider this special form of spring.

665. Various small tools relating to the balance-spring are described in articles **350, 360—1.**

666. To harden gold springs.—Gold detent, thermometer, suspension and balance springs can be obtained of a high degree of elasticity (see p. 773 of the *Treatise* and art. **113**). Rolling hardens them, but renders them very brittle. They can be made supple and elastic, not by hardening, as in the case of steel, but by annealing, care being taken not to exceed a certain degree of heat. The spring may be coiled on a block and placed in a tube that has a smooth steel lid, then heat the tube in the flame of a spirit lamp, and, as soon as the steel is of a blue temper, remove the flame and allow the whole to cool.

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Or ignite two peats and, as soon as their surfaces are white and flakey, place the spring coiled on a block between them, so that it is completely surrounded ; leave them in this position until the whole is quite cold.

Others anneal by keeping the spring in boiling oil for a definite period.

The hardness of a gold spring increases with the proportion of alloy it contains, and, if well annealed, it will be very elastic and will break when bent too far, as in the case of steel.

INDEX AND ENDSTONE CAP.

667. Any watchmaker should be able without difficulty to make these pieces. The external edge of the endstone cap is polished while cemented to the end of a chuck by holding a spindle, with a conical hole at the end large enough to enclose the cap, against it, the hole being supplied with polishing powder.

The projecting portion of the ring of the index is polished, on its upper surface, in the same manner, and the bevel is polished from the upper side by using a spindle with rounded end.

To polish the two arms that are respectively the pointer and the curb-pin arm of the index, it is fixed on a bar, *c d*, fig. 17, plate VIII., which must be supported between the runners of a pair of turns. The pin, *a*, set in the ferrule, oscillates between the arms of a fork *f* screwed to a runner of the turns, and by using a bow on the ferrule a rapid backward and forward movement is given to the index, while a large-size smoothing or polishing iron, charged with oilstone-dust or rouge, is made to traverse the two arms both lengthwise and crosswise: the operation is finished with a piece of wood and a burnisher.

The oscillating movement may be produced by a finger resting on the ferrule, or by leaving the runner unclamped, the collar *r* resting against the poppet-head.

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Other methods are, of course, adopted, but the above can be resorted to by any watchmaker.

When the index is flat, the surface of the bar *c d* should be below the line of centres.

668. To ease an index on its endstone cap.—It is a common but bad practice among watchmakers to scrape the inside of the ring of the index or to cut it through. A better method is as follows :—Resting the index on a cork, cover the inside of its ring with oilstone-dust and make the cap rotate in its seat by means of a pinion calliper, the two points of which are inserted in the screw-holes. The operation is repeated as often as may be required.

DIAL-PLATE.

669. To cut the large hole in a timepiece dial-plate.—Some workmen cut the hole in the dial-plate of a timepiece by means of a strong pair of compasses, one leg of which terminates in a bullet-nose that is supported in a central hole, while the other is provided with a hardened cutting point that serves to scrape out a groove.

Others use a rule that revolves on a conical point and carries a slide with a tracing point which can be replaced by a sharp-pointed cutter. Proceed in exactly the same manner as when using the compass, but a greater force can be applied, because, while one hand steadies the centre, the full force of the other is applied to the cutter.

A third and still simpler plan is adopted by some clockmakers. A rod of the diameter of the central hole, and a cutter of which only the cutting point projects, are gripped in the vice at a distance apart equal to the radius of the hole to be made. Then passing the rod through the central hole and holding the plate in both hands, rotate it, at the same time applying pressure so as to cause the cutter to form a groove. When a moderate depth has been attained, invert the plate and cut one on the opposite side.

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Care is necessary when the grooves are on the point of uniting; on the removal of the centre, smooth the edge with a half-round file. Some workmen consider it more convenient to set the cutter and rod in a thick piece of wood that is rounded at the top and made flat on its two sides towards the bottom, so as to be firmly held in the vice.

The method adopted for determining the position of dial-feet holes is given in article **676.**

DIALS.

ENAMEL DIALS.

670. To make an enamel dial.—The following particulars in regard to the method to be adopted in making such a dial are taken from the report of a lecture* delivered by Willis, a well-known manufacturer in Clerkenwell:—

The copper blank is first to be made. This is done by laying a piece of the metal on a steel die of the required size, and forming the centre hole with a conical punch. File off the top of cone thus formed, and open the hole with a round broach to correspond with the hole in the die; cut the copper round, leaving sufficient to make a rim to hold the enamel, and the rim must then be reduced so that the dial may not be thicker than is necessary. Now lay the copper on the frame and mark the places for the feet, which may be brazed on with spelter or soldered by using silver-plated wire. The latter method is by far the best. A piece of the wire having been cut off with a flat end is moistened in the mouth, placed in position, and the blowpipe jet directed against it. On attaining a red heat, the silver will run down and form a joint as firm as the metal itself,

* *Horological Journal*, Vol. XIX. (1876—7), p. 66.

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without there being any risk of displacing the foot. After cleaning and pickling in dilute sulphuric acid, the blank is laid on a die, flattened with a spatula, and slightly raised lunette-shape: it is then ready for enamelling.

The enamel (for composition of which see **194**) is reduced to a powder as follows:—Place a small quantity in the furnace (**251**), and when nearly red-hot plunge under cold water. It may then be easily broken and pulverized in a mortar to about the coarseness of sand, the exact degree depending on the enamel used, and great care is needed in grinding to obtain the grains of even size. Now lay on the fine powder (made into a paste with water) by means of a spatula, tapping lightly to secure an even surface; the "blank" is then laid on a cloth to dry. Set it afterwards on a block covered with soft wax, and lay on the top surface; this is a delicate operation since it is necessary to avoid making the surface either concave or convex. The dials are next dried and fired, but not run to a level surface, as they would not in that case stand the second firing. When cold, examine them carefully, picking out any spots with a graver. Grind off the surface level, and, after washing and drying, again introduce into the furnace to obtain a shining surface.

671. The blank, now known as a *white*, is thus in a condition for painting the figures. Divide the surface with pencil-lines while it is fixed on a division-plate provided with a revolving radial rule. The paint used is a black enamel that fuses at a lower temperature than the dial itself. This is ground extremely fine and made into a paste with oil of spike lavender. Draw in the hour numbers roughly and dry with very gentle heat; cut off their ends with an ivory point in a pair of compasses, and rule them true with a similar point. Other marks on the dial are painted in with a fine brush. After again firing the dial, resting it on a flat fireclay ring, set it to lie flat, by pressing lightly and evenly, while still hot, all round the edge with a pair

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of spatulas ; file off superfluous copper on the edge, smooth with water of Ayr stone and gild.

The hole for seconds dial is next cut (**677**), an operation which requires considerable care. The piece is fixed in its place by a cement composed of bleached shellac and flake-white (or ordinary white sealing-wax), which is melted by holding the dial over a lamp while the separate piece is in its place, the cement being first applied round its edge. When cold, remove the excess with a knife, and the dial is finished. A better plan, however, which is very generally adopted in the best work, consists in exposing a clean surface of copper in both the dial and seconds circle, their contiguous edges being bevelled so as to form a V-shaped groove all round. An easily fusible solder (No. IV., art. **128**) is then run in at the back, and flux applied, when a perfectly clean and sound joint is obtained.

672. To drill an enamel dial.—Take a hard well-sharpened graver and moisten it with turpentine or turpentine that contains camphor in solution, or in the following mixture, which is still better :—

Turpentine	62	parts by weight.
Oxalate of potassium . .	4	„ „
Camphor	4	„ „

The two latter substances are reduced to powder and dissolved in the turpentine, and 2 parts by weight of sandal wood may be added.

The graver point is placed on the dial at the point at which a hole is required and the graver is rotated backwards and forwards between the fingers. Practice, acquired by drilling a few holes in broken dials, will soon indicate the degree of pressure that can be applied without fear of accident. Some workmen prefer only to apply the maximum pressure while the graver rotates in one direction, reducing it during the opposite movement ; others hold the handle or tang in one hand and rotate the graver with the other, always in the

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same direction. The operation is continued, frequently arresting it, however, in order to set the graver and moisten it, until the copper-plate and back enamel is perforated.

As soon as this point is reached, take an iron or steel spindle, pointed at both ends, and having a ferrule at one end. The opposite point must be more obtuse than the hole already formed in the dial. Charge this end (*g*, fig. 4, plate X.) with emery or oilstone-dust, and support *d* in one of the holes at the side of the vice; when the spindle is caused to revolve by a bow the enamel on the contour of the hole will be rapidly removed. When the copper disc is reached, a fine-pointed and sharp graver must be used to remove the metal that is exposed as well as that which is covered with only a thin layer of enamel; then renew the operation with the spindle, occasionally drawing a file along the surface of the acting cone. Or the cones of solid emery to be obtained at the tool-shops can be used for this purpose. A workman must be very careless or unskilful to fail in rapidly drilling a hole in a dial by this method without accident, and he may carry on the process easily until the hole is large enough to permit the introduction of a rat-tail file.

673. *To enlarge a dial-hole with a rat-tail file.*—As an extra precaution the contour of the hole on either side may be coned with a spindle as explained above, so as to reduce the thickness of enamel to be acted on by the file; but a watchmaker that has had any experience can dispense with such a preliminary, which we would at the same time recommend.

The file must enter the hole freely. If only the point can do this, the file must be held very short, so that the finger may come in contact with the dial before the larger diameter of the file locks in the hole, as this would almost certainly crack the enamel. Some workmen avoid such an accident by forcing on to the file a rather long cork of small diameter.

With a view to avoid scratching the face of the dial in

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case the file is drawn out of the hole in its backward movement, it is well to round off and polish its point.

During the forward movement a slight circular motion is given to the file, and in returning no pressure is to be applied; the file must merely slide over the surface. It is dipped from time to time in the liquid mentioned in the last article. When the hole is large enough, a conical spindle should be used to smooth its edges as in the earlier stages of the process.

674. To remove enamel from the back.—To remove portions of the enamel from the back when it touches parts of the motion work, &c., various methods are adopted.

The little spindles of solid emery that may be obtained at tool-shops may be used for the purpose.

Some watchmakers use a flattened lead ball perforated at its centre and carried on a taper arbor, forming a kind of small grindstone, rounded across its rim. The arbor is set up between the runners with a bow on its ferrule, and the edge of the lead disc is moistened with water, and emery powder sprinkled over it; when set in rotation the surface to be removed is held against the lead, the necessary pressure being applied by the finger against the other face. Water must be frequently sprinkled on the surface so as to avoid heating, and to maintain the emery in its place, and the dial is washed occasionally to examine the progress of the work.

In place of lead, some use emery formed into a solid block with shellac or various kinds of cement (**165**); it is centred on a large taper arbor, and should be at least a quarter of an inch thick and rounded at its edge. Such a disc is very hard when cold; it is used in the manner explained in the last paragraph, but wears more rapidly than the lead disc, if this latter is well made and supplied with emery of the right degree of coarseness, in sufficient abundance and evenly distributed.

675. Dials fixed by screws through the edges.—The screw-holes at the edge are drilled in the manner already

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explained in article **672**, and the centre hole is enlarged as there described, if this is found to be necessary in order to permit the free passage of the hour wheel. The diameter of a dial may be reduced if it is too large in the manner explained in article **678**. When it has been thus prepared, place it in position, the XII being exactly opposite the pendant, with the movement in the case, and close the bezel. If the dial is found to shake under the bezel it should be fixed with three or four small wedges of pegwood, care being taken that they do not subject the dial to much pressure. The accuracy of the position may be tested by holding a stretched piece of fine catgut over the dial, and observing whether it passes at the same time through the middle of the pendant, the centre hole, the XII and the VI. When the dial is thus found to be properly placed, mark one of the screw-holes on the watch-plate through a dial-hole. Some care is necessary in doing this lest the hole is marked excentrically or the dial is displaced by pressure against one side of the hole in it, which might result in the dial being cracked by the screw. Now remove the plate from the case and drill its screw-hole in the drilling tool; tap it and fit the screw. Replace the plate in the case, and, after fixing the dial to it with the one screw thus fitted, carefully mark the second hole, &c.

Some workmen expedite the operation by marking and drilling the two holes at the same time; but if at first they do not succeed in making them in the required position they materially increase the time occupied, as one hole at least requires to be bushed, &c.

676. Dials held in position by feet.—If the dial has feet, and it is required to adapt them to the plate, they must be first carefully bent straight; then take a piece of stiff cardboard of moderate thickness, and, laying it on a piece of lead, punch out with a sharp-edged punch or other means a round hole of the diameter of a foot. Having inserted one foot in this hole, and placed the card on a flat surface with

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the dial uppermost, apply a slight pressure to this latter so, as to mark the position of the second foot. Then punch out a second similar hole at the point thus indicated. If the operation has been properly conducted the two feet will enter the holes in the cardboard easily, but at the same time without constraint or shake, and they should project on the opposite side.

It now only remains to cut out the cardboard to the size of the plate, and, after making a central hole and a mark to exactly correspond with noon, to place it in position in the frame and under the bezel, as though it were the actual dial. Then mark the two holes for the dial feet, using a sharp-pointed chamferer that just fits the hole, held vertical and rotated by one hand, while pressure is applied by a finger of the other hand.

Some workmen merely prick holes in the card with some sharp-pointed instrument, or even force the feet through it at all risks ; hence it happens that feet are often bent out of the vertical, and, in order to be able to bend them into the required position, it becomes necessary to enlarge the holes in the plate and bend the dial feet.

677. To cut a large hole in a dial.—To set a seconds dial.—This operation is performed in the ordinary chuck lathe or in a mandril.

The hole is cut by the aid of a ring of thin iron or copper cut with saw-like teeth round its edge, as shown at v, fig. 9, plate X., kept in rotation and charged with fine emery and oil or water or, what is better, turpentine. The mixture described in article **672** will secure a still more rapid action.

It is advisable that the thickness of the ring be made to gradually diminish from *e* towards *i*, as indicated by the section at s, so as to prevent it from choking and probably cracking the dial.

The following arrangement may be adopted :—Prepare a strong ring with a projecting internal ridge, shown in section

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at A B C, fig. 9, plate X.; cement the dial, *g d*, to this ridge, or fix it by any convenient means, and attach this supporting ring to a chuck that rotates in a direction opposite to that of the cutter, but much less rapidly. On reaching the copper disc, reverse A B C and repeat the above process on the back enamel. The copper is thus exposed on the two sides. On filling the deeper groove with dilute nitric acid (**155**), the metal will gradually be eaten away, and the acid should be renewed as often as may be needed. It then only remains to smooth the edge, bevelling it on the front side, and to cement the seconds dial in position (**671**).

The use of acid may be avoided and the cutter passed through the copper, but greater care must be exercised, because the work is more difficult when operating on metal. It will, however, not be difficult after a few trials.

Willis recommends that the dial be cut straight through, commencing from the back and using emery and oil, the dial being cemented on a brass block immediately below the cutter, and rather less in diameter than the hole produced. He mounts the cutter on a stock that is provided with a pump-centre, the point of which is maintained throughout the operation in the small hole or point that marks the centre of the hole. The great advantage of this method is that the taper of the hole is in the required direction and no filing is necessary.

678. To reduce the diameter of a dial.—Resting the dial in an inclined position against a block, file its edge with a smooth or half-smooth file, which must only be allowed to act while advancing, and is at the same time displaced sideways and turned so as to follow the contour of the dial. The file should be dipped occasionally in turpentine, and when sufficient enamel has been removed, pass a new emery stick over it to remove the file marks.

679. To remove a figure or name from a dial.—To re-polish the enamel.—Oil of spike lavender may be employed for erasing a letter or number.

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Enamel powder made into a paste with water, oil, or turpentine, is also used for this purpose. It should be previously decanted (**168**), so as to obtain several degrees of fineness. The powder used for re-polishing the surface where an impression has been removed must be extremely fine. It is applied on a piece of pegwood, although some use ivory.

The last and best system is to employ diamond powder. Take a little of the powder, made into a paste with fine oil, on the end of a copper polisher, the surface of which has been freshly filed and slightly rounded. On rubbing the marks they will be seen to rapidly disappear.

The surface is left a little dull; it may be rendered bright by rubbing with the same powder mixed with a greater quantity of oil and applied with a stick of pegwood.

Watchmakers will do well to try several degrees of fineness of the diamond powder (**169**) on disused dials.

To repair a dial with enamel applied cold.—This has already been explained in article **195.**

METAL DIALS.

80. To restore a silver dial.—We proceed to describe several methods of doing this, but would at once observe that when the earlier ones are adopted, the hours, if they are painted, necessarily disappear; whereas they can be retained by resorting to the last method (article **685**), although great caution must in that case be taken; moreover, it is much more difficult to accomplish than the others.

681. First method.—This is the most expeditious system, and at the same time the most certain of success.

If the hours are in enamel, there need be no fear; if engraved and filled with black composition, this will disappear, but it can be replaced without difficulty. There remains the case of painted hours to be considered.

First make thin marks with a fine point along the lines of

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all the figures, taking care not to pass beyond their ends: and do the same for the dots and lines that indicate the seconds. By using a glass and following the instructions given in article **697**, no difficulty will be experienced in doing this, and the fine lines and dots thus made will afford sufficient guide for re-making the hours.

Begin by cleaning the dial with a brush and fine pumice-stone so as to remove spots and slight scratches.

682. *To frost the surface.*—In order to frost the surface of the dial, take a spirit lamp with large wick, and direct a blowpipe flame from it against the under side of the dial, which is held by one hand with a hooked support B, fig. 10, plate X. If the flame is gently directed over the entire surface of the back, a good dead surface is obtained that resists a moderate degree of friction either in soaping with a fine sponge, or washing in a large quantity of water, or in applying soft bread and oil of spike lavender to erase irregularities or marks made in painting the figures.

The application of the flame is several times repeated, so as to obtain a decisive and even frosting; but it is necessary, with a view to avoid distorting the thin metal, to place an iron or copper washer *a a*, fig. 10, behind the dial. The flame oxidizes the surface of the metal; that is to say, it causes the oxygen of the air to combine with the copper which is alloyed with the silver.

683. *Pickling or bleaching the dial.*—Introduce sufficient warm water into a suitable flat vessel to completely cover the dial, and gently pour into it a few drops of sulphuric acid (oil of vitriol), so that the two liquids are in the proportion of about 1 to 10; then lay the dial in this dilute acid for a period that varies from half to one or two minutes. The frosting will first become yellow and then of a beautiful white colour. Wash it in a large quantity of water, wipe with a fine linen rag, and apply the flame momentarily to the back in order to prevent the formation of spots on the surface.

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When several dials have to be operated upon, the acid is put in a porcelain dish and boiled by a lamp. Then place each dial for a moment in it, wash in an abundant supply of water, and dry by tapping with a fine linen rag.

684. Second method.—For the benefit of such as care to experiment with it, we add the following method :—

Brush the dial with a coarse brush and pumice-stone reduced to an impalpable powder until no scratches are visible. Make it red-hot and allow to cool. Then dip for two or three seconds in a porcelain vessel containing dilute sulphuric acid ; on removal it will be found to be white, but rather dull. In order to produce a clear frosted surface, place the dial in a mixture of—

6	parts by weight	of	nitric acid of 1·22 sp. gr.*
21	„	„	sulphuric acid.
50	„	„	water.

Allow the metal to remain in this acid until no more globules are seen to form on its surface, then withdraw it and immediately place in cold water. The dial will be observed to be nearly black ; it is then pickled as above explained (**683**), washed well, heated red-hot and, when cold, again pickled ; the operation is concluded by thoroughly washing its surface.

685. Third method—(Taken from M. H. Robert's *Etudes sur diverses questions d'horlogerie.*)—Cover the surface of the dial with a thin layer of soap, and brush it over, taking care to avoid touching the hours if these are not enamelled. This can best be done with a fine brush and pumice-stone reduced to an impalpable powder. When the dial has been made as clean as possible by this means, wash it carefully with water and tartrate of potash (cream of tartar), then plunge it immediately in the hot solution of nitrate of silver (**686**) attaching it to the silver wire which is fastened

* This contains about 1 part of pure acid and 2 parts of water.

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to the zinc and copper discs (**687**); in two or three minutes the surface of the metal will be perfectly frosted and, if each operation has been cautiously performed, the hours will remain intact.

Each time the zinc and copper discs are used they should be cleaned with nitric acid, and rubbed over with pumice-stone.

As soon as the dial is clean, immerse it in the solution; the least delay is apt to cause the surface to become oxidized through contact with the air.

686. *To prepare the silver solution.*—Dissolve 1 ounce* of solid nitrate of silver (lunar caustic) in a small quantity of water; filter the solution and add twice its volume of liquid ammonia. In a separate vessel dissolve 6 ounces of yellow prussiate of potash and 4 ounces of crystallized carbonate of soda in 60 ounces of water, contained in a vessel of enamelled iron, which must be placed on the fire. When near the boiling point add the concentrated solution of nitrate of silver, and allow the mixture to boil for an hour, taking care to add hot water in sufficient quantity to make up for that lost by evaporation; then filter the resulting solution.

687. *To prepare the discs and to plate.*—In order to use this solution for restoring a dial or plating any other object, take two discs about the size of a five-shilling piece, one made of zinc and the other of copper, and, after making a small hole in each, unite them with a copper wire or, preferably, with one of silver. After having attached the dial or other object to this connecting wire, immerse the entire system in a glass or earthenware vessel, and pour over it a sufficient quantity of the solution, previously made hot.

If the object operated upon is perfectly clean, bright and free from all greasy or oily matter, its surface will be found

* If a greater or less quantity of the solution is required, all these quantities must, of course, be increased or diminished proportionately.

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in two or three minutes to be covered with a firmly adherent layer of silver. When only a small piece is treated it will suffice to immerse it in the hot liquor, and rub it with the finger; a bright silvered surface will thus be obtained.

688. To clean and silver the metal dials of clocks, &c.—When the hours are neither enamelled nor engraved, it is necessary to first trace out the several lines and dots in a manner similar to that explained in article **697.**

689. *Ordinary mode of cleaning the dial.*—Very often it is possible to make a silver or plated dial of either watch or clock sufficiently clean by merely brushing with powdered cream of tartar worked up into a paste with water, carefully rubbing round any painted figures with a fine stiff brush. Then wash with clean water, dry by gently tapping with a fine linen rag, and expose to a slight heat. (This is in part the same method as is described in article **685**; the two may be combined.) If the dial is tarnished, it must be silvered as explained below.

690. To plate a brass dial.—*Preparing the silver.*—Place in a glass flask from 100 to 150 grains of pure silver made into thin strips by means of a hammer or rolling mill. Add five or six times this weight of dilute nitric acid so as to completely cover the silver, and warm the vessel, taking care to avoid breathing the fumes or admitting them to the workshop. The metal will be dissolved, and, on continuing the application of heat until all the liquid is evaporated, crystals will be found at the bottom. When cool fill the flask with warm water and, as soon as all the crystals are dissolved, pour the solution into a porcelain dish, previously half filled with water. Place in it a sheet of clean copper of about the size of three fingers, and allow it to remain for the night.

On the following day all the silver will be found attached to the plate, and it can be collected by immersing this in water. Carefully pour off the water from the fine powder thus obtained, and wash it once or twice with an abundant supply of pure water; then dry thoroughly with the

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application of very moderate heat. If the silver thus obtained is not required for immediate use, it should be kept in a dark blue stoppered bottle to avoid the influence of light and moisture.

691. *To prepare the surface of the dial.*—It must be quite smooth, thoroughly washed and dried. M. Robert recommends that the smoothing be accomplished by using soft water of Ayr stone, rubbing in all directions, in order to remove scratches. Or pegwood charcoal can be used, sloped at one end like a whistle, and applied with water. Others employ pumice-stone powder and very fine emery paper.

692. *To apply the silver.*—Take equal parts of rock-salt and cream of tartar, pound them together, and, when well mixed, take about 60 or 80 grains of the mixture, and add to it 15 or 20 grains of silver, prepared as above described, and a few drops of water to form a thick paste, which must be well mixed and worked up on a ground-glass plate by means of a horn spatula to remove all grits. A glass pestle may be used for this purpose.

The dial having been prepared, take up some of the paste with a perfectly clean and rather stiff brush, and spread it over the surface of the dial, rubbing quickly and somewhat harshly. The brush should be worked about in all directions, so as to avoid scratches, until the silver is found to adhere firmly to the dial. According to M. Robert, this rubbing is to be continued until the required grain is obtained; but M. Fournier states that it should be arrested when the surface possesses a lead-grey colour; the dial is then well washed, dried, and the operation re-commenced exactly as before except that the brush used is softer. A good surface will thus be formed, and it will be whiter if the proportion of silver in the paste is increased.

The result attained in great part depends on the skill of the operator, and this can only be acquired by experience.

693. *Observations.*—If the mixture contain too much of the salt or too little silver, the latter will adhere with

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difficulty, and will come off in lumps or scales; moreover, it will not have so white a colour.

As the proportion of silver is increased, the white becomes gradually better; but, on the other hand, if it is in excess the surface will be coarse and uneven.

Too much or too little water will have nearly the same effect.

The colour is worse if the dial has been imperfectly smoothed, and when several days or even hours are allowed to elapse between the cleaning and silvering.

It is essential that the rock-salt and the cream of tartar be perfectly pure; if they contain any earthy matter it will scratch the surface and impair its whiteness.

As soon as the operation is completed, the dial must be washed in an abundant supply of pure water; any neglect in this particular will cause it to blacken. This washing may be performed with an ordinary watch-brush, charged with cream of tartar. Then rinse the dial, and dry, tapping gently with a fine linen rag, and finish by slightly warming it.

694. Gold dials.—It will not be necessary to say much on this subject. In order to restore the colour to a gold or gilt dial, it may be dipped for a few seconds in the following mixture:*—Half an ounce of cyanide of potassium is dissolved in a quart of hot water, and two ounces of strong ammonia mixed with half an ounce of spirits of wine are added to the solution. On removal from this bath, the dial is immediately immersed in warm water; then brush with soap, rinse, and dry in hot boxwood dust. Or it may be simply immersed in dilute nitric acid, but in that case any painted figures will be destroyed. (See **142—153.**)

695. *Another receipt.*—The following is the method ordinarily adopted for colouring gold dials; but it is to be observed at the outset that, although apparently characterized by extreme simplicity, a good deal of skill is needed

* *Horological Journal*, XIX., 96.

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to ascertain when the mixture is of the right consistency, and when the dial has been sufficiently exposed to its action.

Make a mixture of 4 oz. saltpetre, 2 oz. alum, and 2 oz. common salt (the purest attainable), with a very little water. On placing this in a blacklead pot over the fire it will become limpid, and must be allowed to boil until somewhat pasty and of a pale yellow colour, stirring all the while with a stick. Now take two dials back to back that have been cleaned and blackened by annealing, and pass a platinum wire through their centres so that they hang horizontally, resting on a loop at its end ; immerse the dials in the hot colour pot, and, after holding them in it for a short time, withdraw them and immediately immerse in a vessel of nearly boiling water standing close by. The "colour" will then be washed, and the progress of the work can be observed. The dials are again dipped in the pot if necessary, and will probably require about three minutes' immersion in all. It is advisable that the "colour" be thick rather than thin, as in the latter case the dials are apt to be clouded.

696. To re-paint the hours on a dial.—The following system has reference to metallic dials, but the reader will be able to select without difficulty the parts that are applicable to altering and retouching the figures on an enamel dial.

We can answer from experience for its being successful, but would at once observe that it cannot be practised hastily, because some skill is essential in addition to patience and care : with them, success is certain.

697. *First method.*—Before removing the hour figures and the divisions for minutes, mark them with a fine steel point, using a lens and proceeding with great caution. These marks will remain, so that after the dial has been coloured or otherwise treated, it will only be necessary to trace over them with a fine brush charged with ink.

The short horizontal lines at the top and bottom of each figure, termed "serifs," as well as the two circles that enclose

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the minute divisions, can be drawn with a sharpened point of the screw-bar compass.

698. *Second method.*—Lay on the dial to be treated, or on another of the same dimensions that has the hours well marked, a piece of tracing-paper, so that neither it nor the dial can be displaced, and, using Indian-ink and a fine drawing-pen, accurately trace the hour figures and the minute divisions. When the ink is dry, invert the paper and trace the figures, &c., thus obtained on the other side of the paper, this time using a pencil instead of ink. Laying the paper on the dial so that neither can slip, pass with a rounded point of some soft metal over all the figures and divisions. Now remove the paper without permitting it to rub against the dial. If the pencil has been selected of a suitable degree of hardness and the operation skilfully conducted, the marks showing the hours and minutes will be clearly visible, although faint, and, holding the glass to the eye, the several marks must be traced over with a fine brush or pen. If this operation is performed carefully, the dial will present a very good appearance.

699. *Third method.*—Place the dial within a kind of large barrel that has at its centre a thick pivot projecting. The three rules D, F, J, fig. 11, plate X., can be fitted on to this by their central holes so as to rotate on it. Being supported by the rim of the barrel, they will pass very near to the surface of the dial without rubbing against it. From an inspection of the figures it will be evident that D is used for forming the bars of an X, F for those of a V, and J for that of an I. Of course the serifs at either end of a numeral are made with the compass.

It is unnecessary to observe that if the edge of the rim be graduated, and the rules terminated by any convenient arrangement for arresting their motion at the graduations, the hours can be traced on a dial from which all marks have been erased. It then only remains to paint them in with ink.

700. Inks for painting the hours.—Work up some

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clean lampblack in oil of spike lavender. Then add a small quantity of spirit varnish and thoroughly mix the whole. This is applied with a fine brush, and the success of the operation depends very much on the selection of this latter.

701. *Another receipt.*—Mix together ivory black, pure wax, and turpentine ; the more the turpentine is in excess, the more will the ink be coloured. It is best adapted for filling in the figures engraved in dials, and a gentle heat should be applied to impart a smooth surface.

Any irregularities in the painting may be erased by the aid of oil of spike lavender and soft bread.

HANDS.

702. To blue a steel watch or clock hand.—Details in regard to this will be found in article **95.**

703. To set a watch-hand in position.—The most delicate part of this operation is the enlarging of the centre hole of a minute-hand and the closing of the hour-hand socket when necessary. The method of doing the latter operation is explained in article **362,** and appliances for firmly holding the socket are described in articles **353—5,** but, in the absence of any of them, the following expedient may be resorted to :—

Set the hand in cement on a brass plate that has a hole passing through at the point corresponding to the socket. The hole must then be enlarged with a semi-cylindrical drill to a diameter such that it will only be necessary to gently pass the broach through afterwards. The drill must not be worked too rapidly, and the plate may require to be immersed occasionally in water, so as to avoid heating the cement and thus loosening the hand.

When the hole in a watch-hand is too large, it may generally be sufficiently reduced by means of the tool designed for that purpose that is described in article **362.**

704. To redden watch-hands.—Make into a paste

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(while holding over a lamp) a mixture of two parts carmine, two parts chloride of silver, and one part Japan varnish. Having spread some of this over the hands, lay them face upwards on a sheet of copper, applying heat until the desired tint is produced.

GLASSES.

705. To drill glass.—A hole can be rapidly made in a piece of glass by using a steel spindle ground at the extremity as shown at C, fig. 11, plate IV., with three or four faces, and hardened in mercury (**85**). This spindle may be chucked in the lathe, rotated between the finger and thumb, or driven by a bow, the point being moistened from time to time with turpentine or the mixture mentioned in article **672**. The glass operated upon should be held against the blade with the thumb or a pad immediately behind it, and should receive a gentle rocking motion so as to prevent the drill from choking in the hole formed ; and as soon as the point appears on the other side, the drilling should be re-commenced from that side. It is a good precaution to mark the point at which the hole is required with a diamond or the steel point before commencing, and the pressure applied while drilling must be but slight.

706. To cut glass.—It is possible to cut a sheet of glass roughly to any required shape with an ordinary pair of scissors, if the operation is performed under water. Of course a smooth edge cannot be obtained by such means, but it will often be found sufficient.

A more exact method is to use a piece of ignited charcoal or the pastile mentioned below, first making a scratch as a starting-point and holding the heated substance a little in advance of the crack : this will follow the direction in which the hot body is moved. The method is available for dividing glass tubes or other objects of irregular shape.

What is known as the "Berzelius pastile" for cutting

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glass is formed of the following mixture :—Gum arabic, 6 parts ; gum tragacanth, 2·3 parts ; benzoin, 2·3 parts ; lampblack, 18 parts ; and the requisite quantity of water. Mix the gum tragacanth with water and leave it to swell up for some hours ; dissolve the gum arabic in a sufficiency of water, and powder the benzoin finely. Mix the three, forming a paste of such a consistency as to be moulded, the lampblack and a little water being also added. The pastiles are then formed by rolling between two plates.

The diameter of a watch-glass can be reduced by centring it in a lathe, chucking it between two pieces of cork or a pair of cork arbors, and applying a moistened piece of glass to the edge, or an emery stick. When the desired diameter is attained, polish the edge with pumice-stone followed by putty powder applied on a wet cork.

BROACHING.

Round and cutting broaches have been already briefly considered in article **248.**

707. To broach a hole vertically.—A hole in a plate, as, for example, that in a barrel, is seldom maintained at right angles to the surface by young watchmakers when they have occasion to employ a broach. By adopting the following very simple method, success may be assured :—

Take a long cork of a diameter rather less than that of the barrel or other object operated upon, and make a hole in the length of the cork through which the broach can be passed. When the cork has been turned quite true on its end and edge, the broach is pushed through and used to enlarge the hole ; by pressing against the back of the cork it is kept always against the barrel, and the verticality of the broach is thus maintained.

708. To broach and maintain the hole round.—Many workmen either use bad broaches or work them in a jerky manner so as to make striæ within the hole. To avoid

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such distortion when uncertain of the hand, draw the broach somewhat out of the hole and insert in the space thus left one or two pieces of hard wood, forming a kind of jacket, so that at least two cutting edges of the broach may be prevented from acting; the broach forcing its way into the pieces of wood, will carry them round with it. A few trials will enable a workman to employ this method.

When operating on holes that are rather large it is a good practice to use broaches that are semi-cylindrical or triangular, their sections being as shown at C, A, or D, fig. 1, plate XII. C and D are excellent for smoothing a hole, but remove very little metal; A does more work in a given time and, if well handled, will maintain the hole very round. When operating on a large hole, these broaches can be rotated in a brace; but, in the case of small or medium size holes, it is much better to mount them in a drilling headstock like those used by case-makers for the joint holes, and the tools can be revolved by the aid of a hand or foot-wheel, a bow or toothed gearing. Only one precaution need be noted, namely, the necessity of avoiding the application of too much pressure, so that the broach jambs in the hole.

709. To enlarge and broach two holes to correspond.—Let it be required to make the hole indicated by dotted lines at *v*, *x*, in the poppet-head A, fig. 2, plate XII., which has been fitted to the lathe-bar, exactly in the same direction, and of the same diameter as the holes in the other poppet-heads.

Take a steel rod $a\ a^1\ a^{11}$ that exactly fits the holes in P and R, and reduce its diameter from *a* to a^1, in order that it may pass through the hole *v x* in A that is to be broached. The end *a* rotates with friction in a collar fitted to R, and perforated with a hole of the same diameter as *a*. At *i* a small double-edged blade is firmly fixed; this is shown apart at I. A sort of trepan or rose-cutter (see article **443**) formed of a disc fixed to $a\ a^1$ and steadied by one or more pins, of the form shown at J, K, or L is, in some cases

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preferable. The cutter may also be formed on the rod a^1 itself; but since it would then require to be hardened, the body a^1 a^{11} must in that case be drilled to a sufficient depth to hold the directing piece *a* firmly.

It will be evident that the cutter is worked by a brace fitted on *m*. If a sufficiently heavy foot-wheel is available, the axis can be driven by that, a pulley being fitted at a^{11}, and pressure applied at *m* during the motion. The velocity must depend on the nature of the metal operated upon (see articles **296—8** and **482**). When cutting iron or steel, the tool must always be abundantly supplied with oil, turpentine or soap and water, and the entire system must be firmly fixed; if the axis of the cutter is allowed to vibrate, the work will be imperfectly done.

710. Two other methods of effecting the same object are shown at N and S, fig. 5, plate XII. At N there is one guiding plate *d* fixed to the end of the lathe-bar, and it serves to ensure that the hole in the poppet-head (in dotted lines) shall be bored true. In the system shown at S there are two guiding plates *c*, *c*, to maintain the direction of a cutter either between them or external to them. It is unnecessary to say more on this subject; any watchmaker will understand the figures at a glance, and by practically carrying out the arrangements suggested will find out for himself the precautions that are necessary.

SOLID AND HOLLOW SQUARES.

711. To file an arbor or drift square by hand.—The most expeditious mode of making a square, as, for example, that of a barrel arbor, is by using the tool described in article **571**, or one of analogous construction; but in their absence the square must be made by hand.

Soften the jaws of a hand-vice and make four flat faces on them, forming an exact square, either by filing or by attaching pieces by rivets. Having clamped the steel on

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which a square is to be formed in the vice, hold this in one hand and rest it in a recess in a wood block ; with the other hand hold the file, determining its position by laying it on the upper face of the square before applying it to the arbor. After giving one or two strokes, test the truth of the face formed by again laying the file on the upper face of the vice. Then turn the vice through a quarter of a circle and proceed in the same manner ; and so on for the other two faces. Before finishing the square and while there still remains a slight excess of metal on each face, ascertain, by examining the end and measuring the lengths of the faces, whether the square is accurately formed.

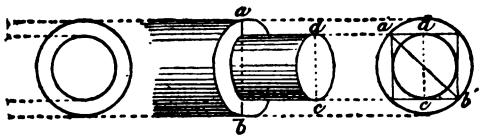

FIG. 27.

Set it up in the finishing turns and draw with a flat file in the direction of the axis along each face. If the square is to be polished after hardening, proceed in the same manner, using an iron polisher in place of the file, to which longitudinal, transverse, and circular movements may be given.

After hardening, the square must be tempered to some shade between pale yellow and a deep blue, according to the purpose for which it is intended.

712. *Another method.*—Let it be required to fit a square to the hole in a keyless winding pinion, the diagonal of which is a^1 b^1, figure 27. Turn the end c d of the rod down until it exactly enters the square hole. Measure with a tapered strip of brass whose edges are filed sharp the diagonal a^1 b^1 ; this will give the diameter a b of the larger

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portion of the rod, as will be gathered from the figure a^1 *d* b^1 *c*.

Turn down the portion of the rod on which the square is to be made and file four faces, each time arresting the action of the file when it is on a level with the smaller cylindrical portion, maintaining the angles equal by observing that the four portions of the circumference retain their equality while gradually diminishing. By a little care and using the square-headed hand-vice described above, success may be assured.

713. To drift a square hole in steel of moderate thickness.—The steel in which it is required to make a square hole must be very soft and thoroughly annealed, otherwise it is sure to crack under the action of the drift or when hammered.

To make the hole in the centre of a stop-finger, for example, the hole must first be drilled of a diameter less than the side of the final square : the drift is then inserted, liberally supplied with oil. On removing the drift, the square is enlarged by means of a fine square file acting on each of its corners ; then with slightly larger drifts the hole is gradually increased to the required size. They are driven with a rather heavy hammer, care being taken to maintain them vertical and with each change of drift a file should be passed over the surface to remove the metal that collects at the corners.

By using a drift of the form shown at E, fig. 9, plate XI., a square hole may be formed at a single operation; but it must be struck sharply and vertical with a heavy hammer.

In the case of thin metal, a hole can also be drifted without previous drilling by means of the tool described in article **367.**

714. To drift a keyless winding pinion, a watch-key, &c.—For this purpose the methods explained above are insufficient on account of the great thickness of metal, which, we repeat, must always be very soft.

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Nevertheless, by using drifts that are very slightly conical, short, and roughed like a file in an inclined direction, and by using a number that succeed one another of gradually increasing diameter, steel of considerable thickness can be treated in the above manner ; but it is far less expeditious than the method explained below.

The piece of steel with a hole drilled through it should be from a third to half as large again in diameter as it is finally required to be. After turning the surface true and the two ends flat, the tube is driven on to a long drift of suitable temper, well oiled and of nearly the diameter of the hole to be made. Clamping this drift in a hand-vice or sliding tongs, rest the steel tube on an anvil with its axis and one face of the drift parallel to the surface, and forge the tube with a medium size hammer. Turn the drift through a quarter of a circle, again forge the tube, and so on. Care should be taken that the drift is forced further into the tube from time to time, oil being at the same time applied.

A punching machine is also very serviceable for the purpose of drifting.

Sometimes the attempt is made to forge the metal red-hot, but this is much more difficult on account of the rapidity that is needed in threading the hot steel, hammering and removing it. Moreover, the steel has to be heated several times and is apt to be burnt.

If the method above explained, in which the metal is kept cold, is carefully performed, it succeeds very well, but it must be observed that steel is often met with that is irregular in composition and cracks.

TO STRAIGHTEN A ROD, PLATE OR WHEEL.

715. A steel rod.—When the rod is short use a large pair of sliding tongs or a hand-vice, the jaws of which have been softened in order to make a groove in each parallel to their edge. Placing the rod in the cylindrical recess thus

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formed between the jaws, fix one side of the hand-vice in a bench-vice, holding a spirit lamp near the jaws and, as the steel changes its colour, tighten the slide or screw of the former. When the metal assumes a blue colour and the jaws are as tight as possible, remove the lamp, allowing the whole to cool slowly or by applying water.

The jaws should be formed so as to bend the rod rather more than is ultimately required, because steel on being released is apt to partially recover its initial curvature.

When the rod is long grip its two ends in the frame of a fret-saw, which should be somewhat strong. Then hold a lamp under the rod, at the same time stretching the steel more and more, and allow the steel to remain stretched until quite cold. If it has been sufficiently stretched the metal will be rendered perfectly straight.

716. A plate, escape-wheel or keyless steel wheel.—At page 286 of the *Treatise on Modern Horology* is given a method of trueing a cylinder escape-wheel that has been cockled in the hardening; the following is a modification of the process there described.

In the middle of a square plate that is moderately thick, fit a strong screw with a large and long head; this screw must pass freely through a disc that is perfectly flat and fits easily into the upper side of the escape-wheel. Now fix the plate between the jaws of a bench-vice, and, placing the wheel between this plate and the disc with a moderate pressure applied by the screw, hold a lamp to the under side, gradually tightening the screw as the steel changes colour so as to obtain a maximum pressure when a blue temper is reached. Leave the whole to cool in position.

717. A verge, small arbor or pinion staff.—When steel is sufficiently tempered, it may be laid flat on a smooth piece of copper held in the vice and flattened by hammering as in the case of an ordinary rod; but if it is hard the blade of the hammer must be used. Every watchmaker knows, for example, that a verge is straightened by striking with

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the blade against its concave side while the convex side rests flat on a smooth anvil. By the action of the hammer the side that is struck becomes a little longer, thus straightening the staff. It is not usually necessary to remove the marks left by the hammer, but if this has to be done the operation should be continued beyond what is necessary to straighten the metal, then temper it to a blue colour and allow it to cool.

A small smooth taper arbor and a pinion staff of a watch or timepiece can be straightened by resting it on a wood block and rubbing the concave side lengthwise with a worn file of medium cut, applying considerable pressure, the arbor being firmly supported below to avoid breakage. The result is the same as with the blows of a hammer, but the marks left are barely visible.

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TABLE
SHOWING THE
SIZES OF WATCH MOVEMENTS,
ON VARIOUS SCALES.*

French Line sizes.	Value in English inches.	Value in French millimetres to nearest unit.	Lancashire sizes that most nearly correspond.	Value in English inches.
10	0·888	22—23		
11	0·977	24—25	} The French sizes 10 to 12 are not represented on the Lancashire scale.	
12	1·066	27		
13	1·154	29	0	1·166
14	1·243	31—32	2—3	1·233—1·266
15	1·332	34	5	1·333
16	1·421	36	7—8	1·400—1·433
17	1·510	38—39	10—11	1·500—1·533
18	1·598	40—41	13	1·600
19	1·687	42—43	15—16	1·666—1·700
20	1·776	45	18—19	1·766—1·800
21	1·865	47—48	21	1·866
22	1·954	49—50	23—24	1·933—1·966
23	2·042	52	26—27	2·033—2·066
24	2·136	54	29	2·133
25	2·220	56—57	31—32	2·200—2·233
26	2·309	58—59	34	2·300
27	2·398	61	37	2·400
28	2·486	63	39—40	2·466—2·500

* Compiled from data given in "A few facts connected with the Elements of Watch and Clock Making." By C. Frodsham. (1862.)

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Explanation of the above table.—The measurements are taken across the pillar plate.

With a view to facilitate reference, the series of sizes on the French line scale are taken as a basis, as it covers the widest range, and only those sizes on the Lancashire scale that correspond to this series are given; the figures that indicate sizes on these two scales being printed in somewhat heavier type. When only a single Lancashire size is mentioned opposite to a line size it is to be understood that the two very nearly correspond, and if two numbers are given on the former scale opposite to one on the latter, it means that the French size is intermediate between the two on the English scale. Thus the line size 18 is almost identical with the Lancashire size 13, and their exact difference can be ascertained from columns 2 and 5 of the table. On the other hand, the French size 20 is intermediate between the English sizes 18 and 19, and the error that would be made by adopting either number as an equivalent can be at once determined by comparing the respective values in inches.

In a similar manner the third column, giving sizes on the millimetre scale, can be used in conjunction with column 1 or 4; indeed, the table affords a means of approximately ascertaining the size of a movement on any one scale when it is known on any other.

The rule for determining the value in inches of any size on the Lancashire scale is as follows:—Taking an initial inch, add to it 5-30ths of an inch (an allowance for the "fall," or room to enable the movement to open and shut in the case), and the number of thirtieths of an inch indicated by the size-number on the scale. Thus a 16-size movement will measure, across the pillar-plate, 1 inch plus 5-30ths plus 16-30ths, or 1 21-30th inch. This stated decimally is 1·7 inch, as seen from the table. Similarly any Lancashire size that may be required, whose value is not given in the table in inches, can be at once converted.

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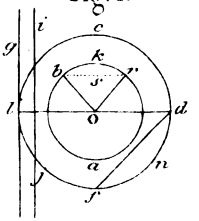

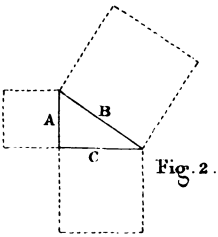

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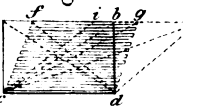

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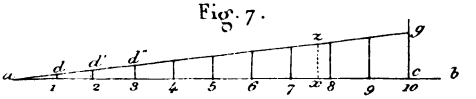

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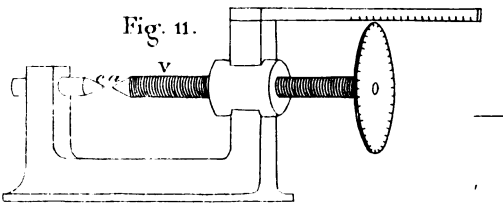

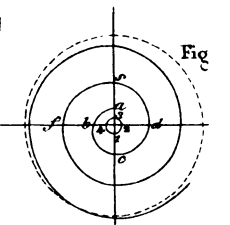

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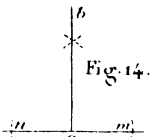

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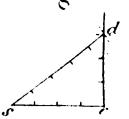

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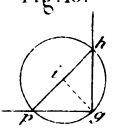

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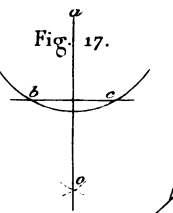

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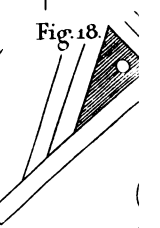

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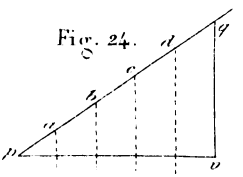

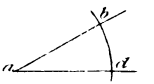

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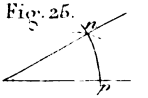

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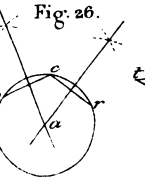

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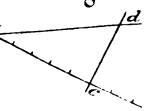

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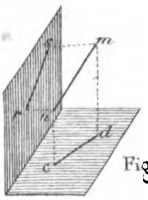

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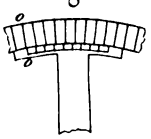

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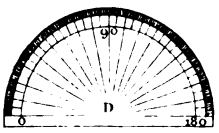
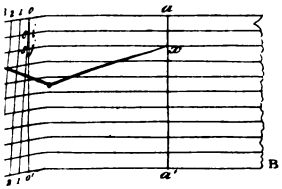


Fig. 8.



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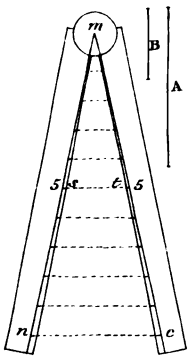


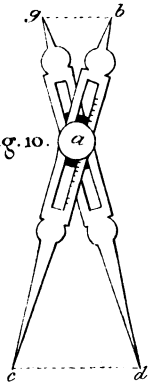
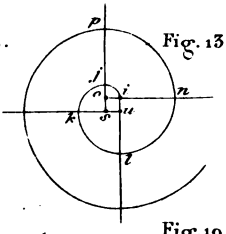
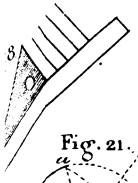


Fig. 10.

Fig. 12.

Fig. 13.





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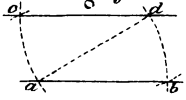

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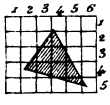

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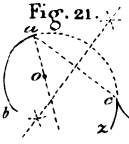

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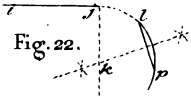

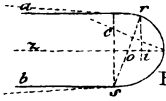

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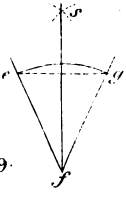

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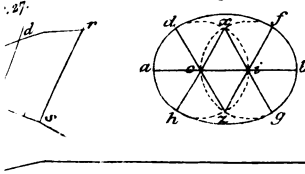

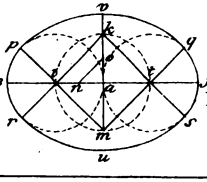

Fig. 29.

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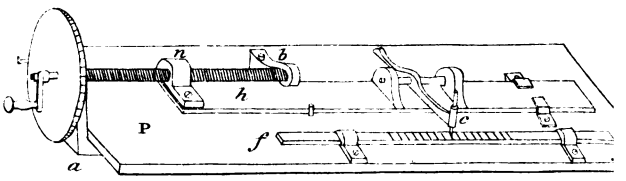

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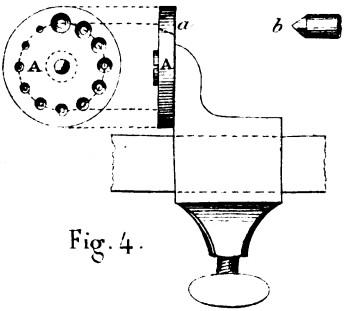

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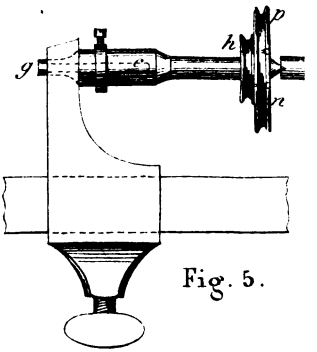
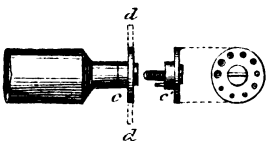


Fig. 5.

Fig. 7.

Fig. 8.



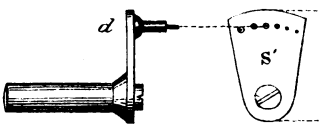


Fig. 11.

Fig. 12.

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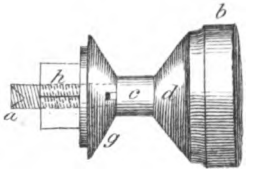

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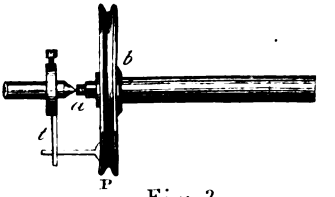

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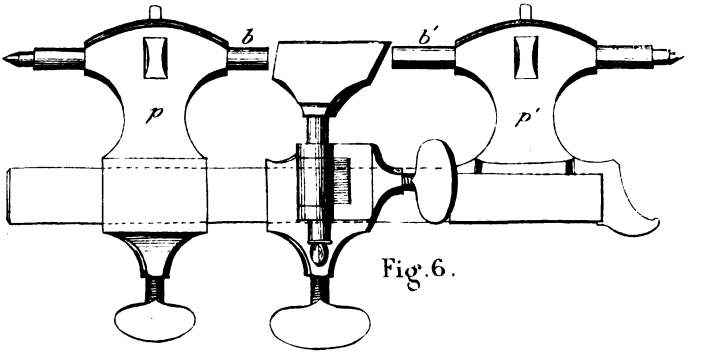

Fig. 6.

Fig. 9.

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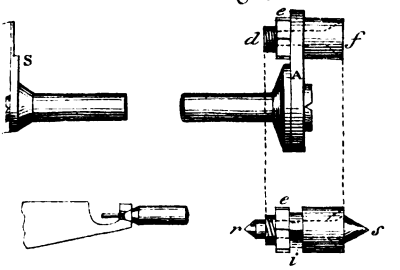

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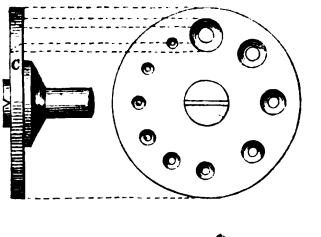

Fig. 14.

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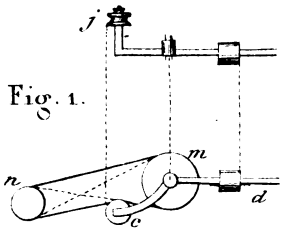

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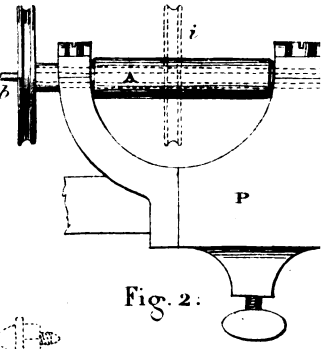

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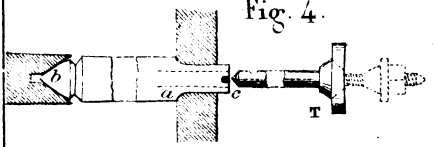

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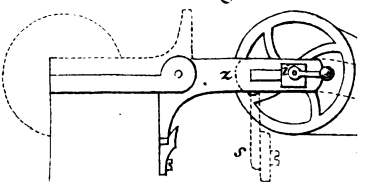

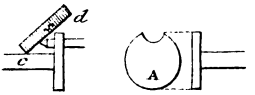

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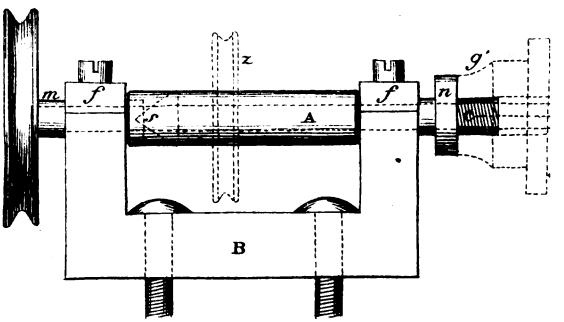

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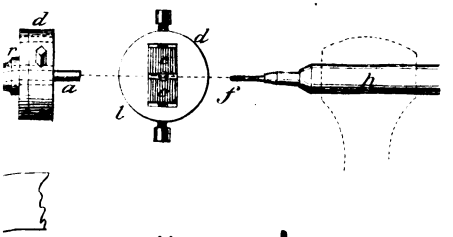

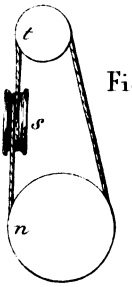

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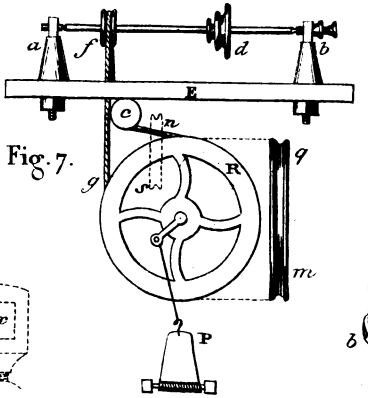

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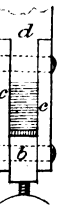

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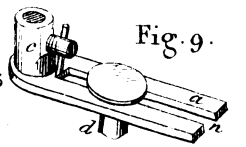

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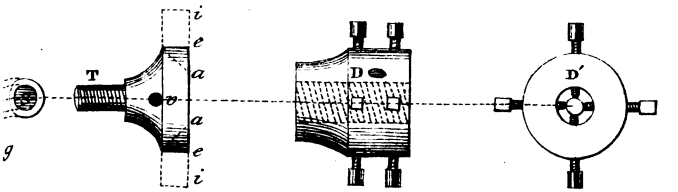

Fig. 10.

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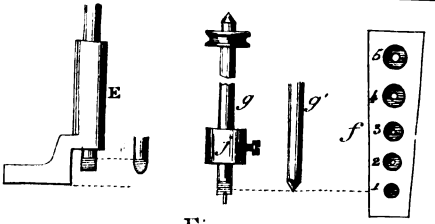

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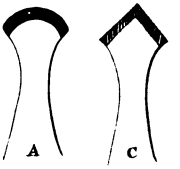

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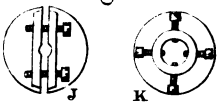

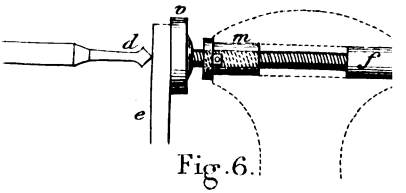

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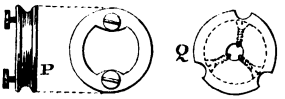

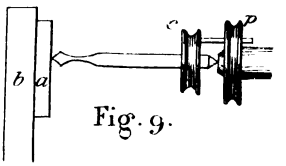

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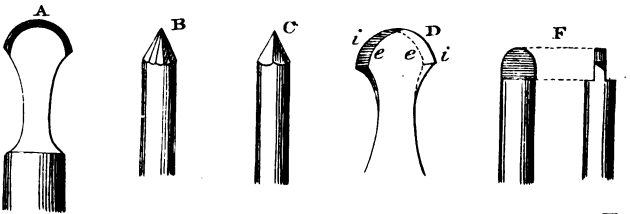

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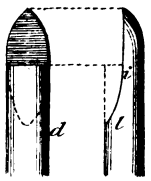

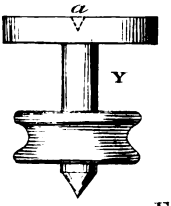

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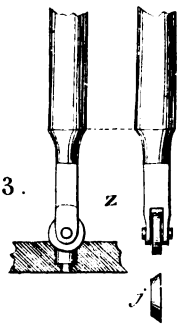

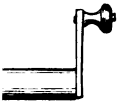

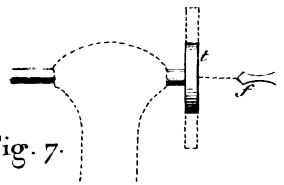

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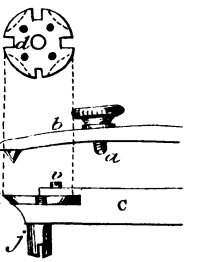

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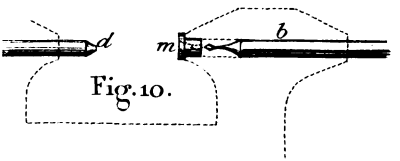

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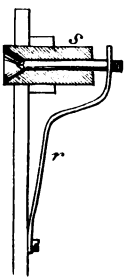

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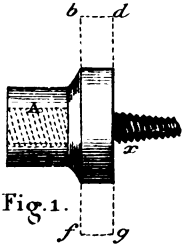

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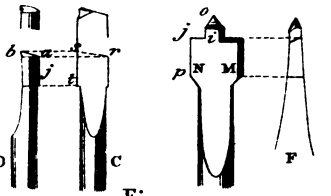

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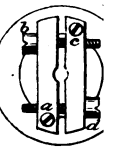

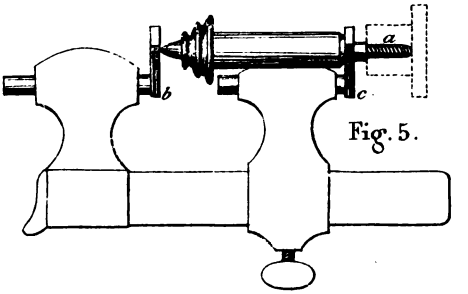

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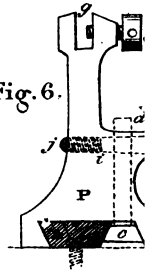

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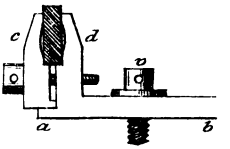

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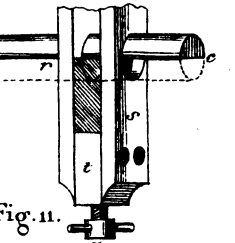

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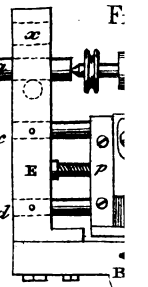

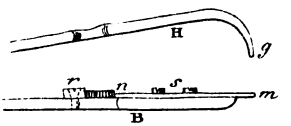

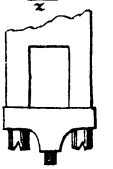

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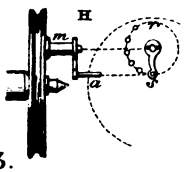

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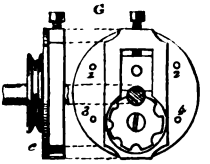

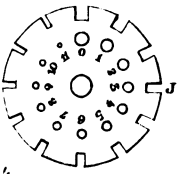

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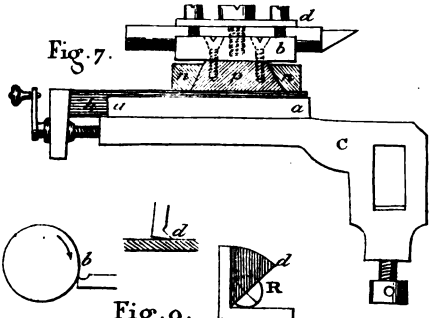

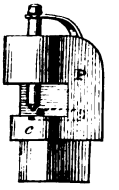

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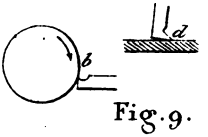

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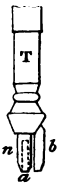

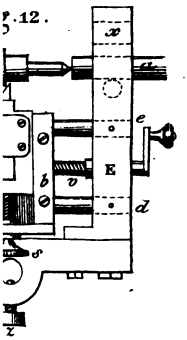

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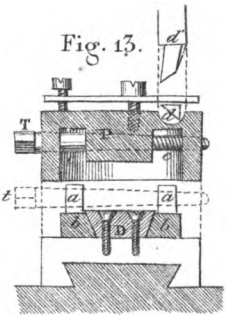

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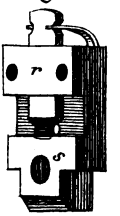

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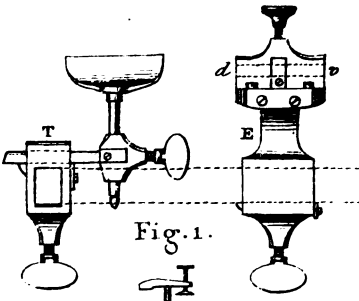

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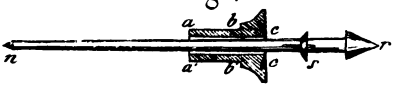

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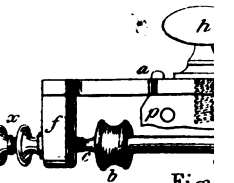

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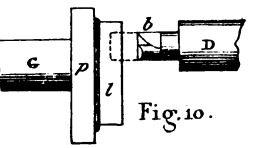

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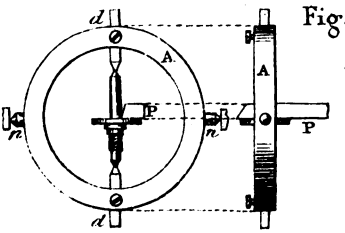

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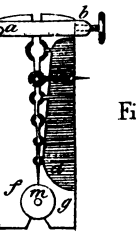

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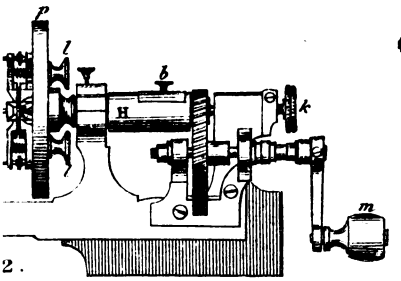

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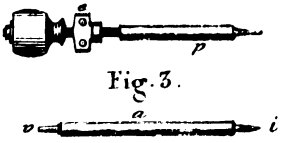

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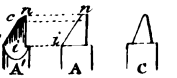

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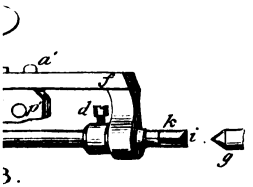

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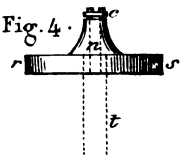

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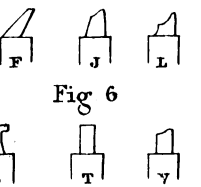

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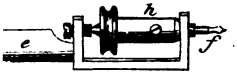

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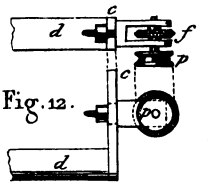

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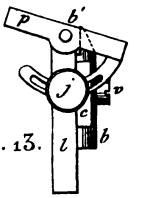

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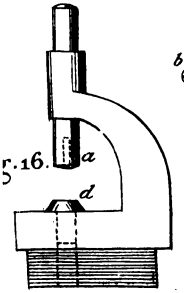

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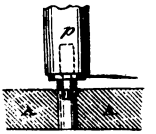

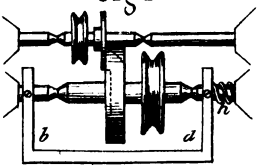

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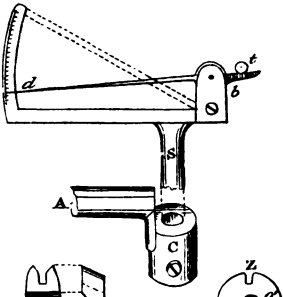

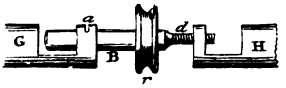

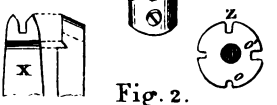

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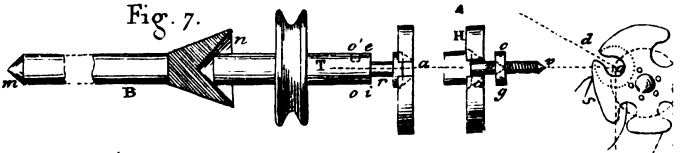

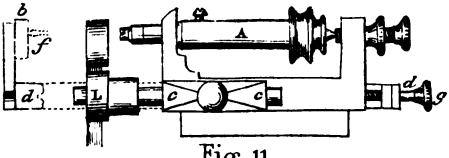

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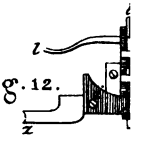

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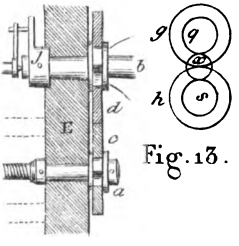

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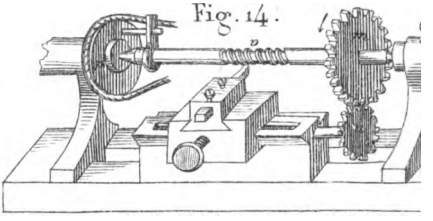

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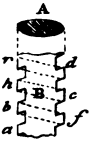

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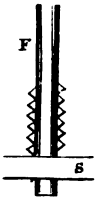

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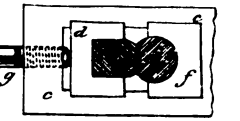

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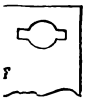

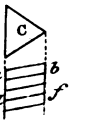

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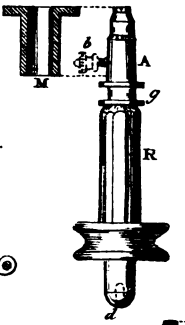

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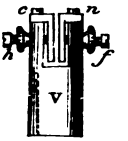

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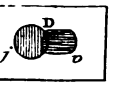

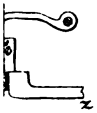

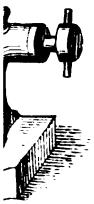

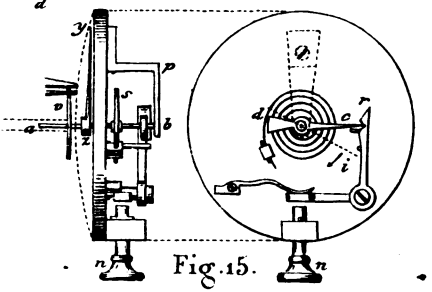

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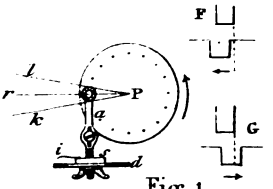
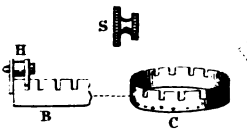


Fig. 1.



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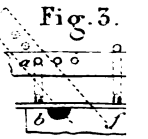
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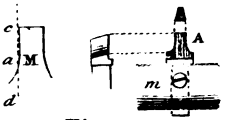

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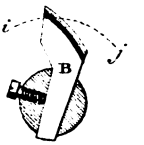

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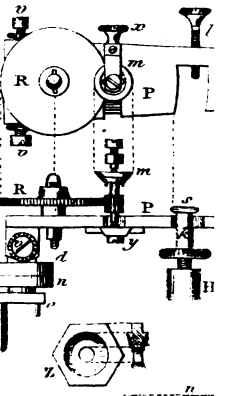

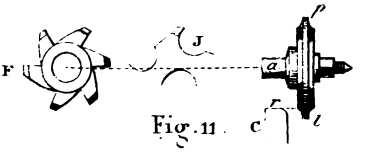

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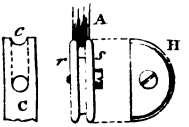

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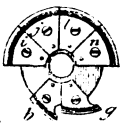

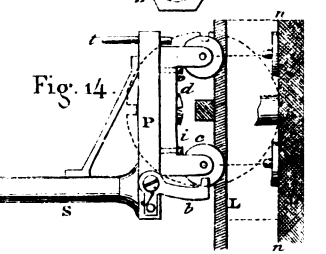

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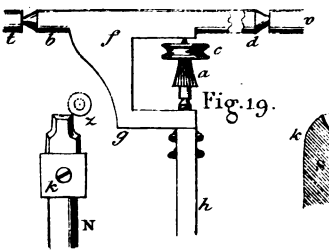

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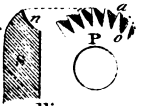

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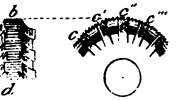

Fig. 21.

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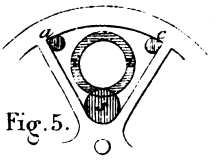

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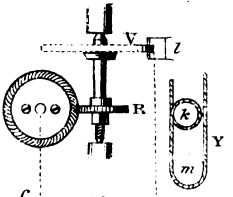

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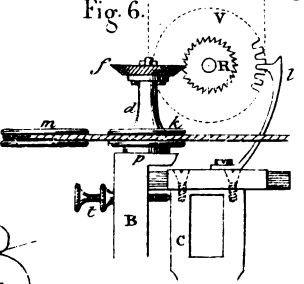

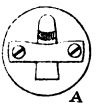

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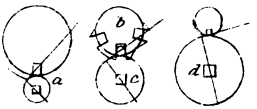

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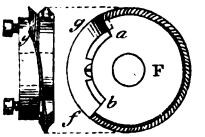

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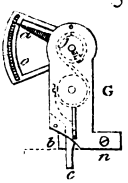

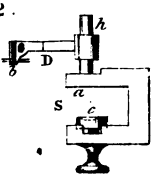

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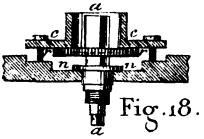

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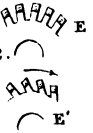

Fig. 22.

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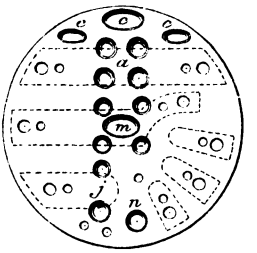

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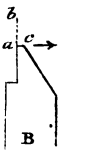

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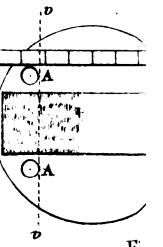

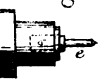

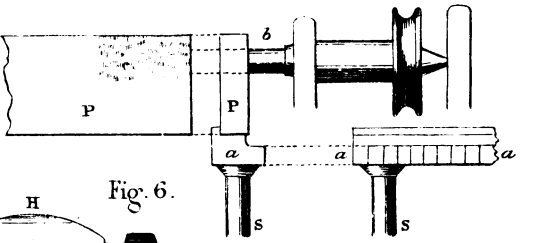

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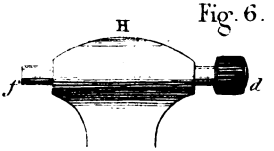

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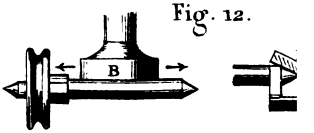

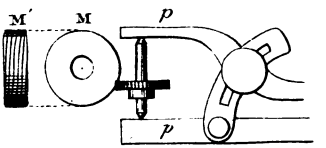

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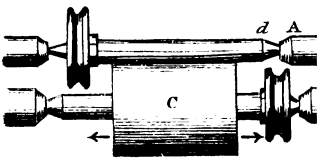

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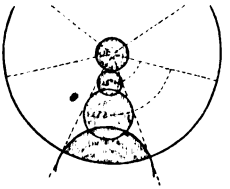

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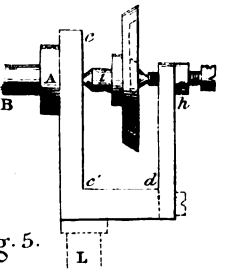

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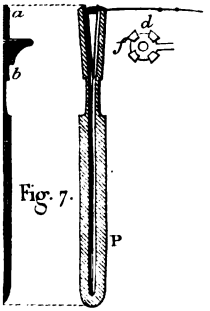

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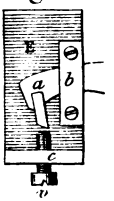

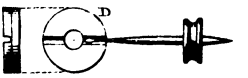

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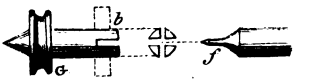

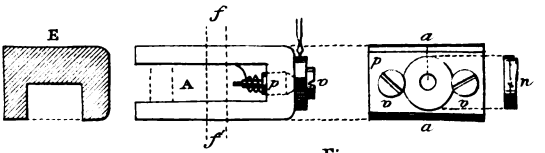

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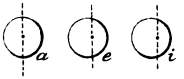

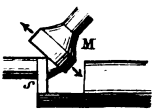

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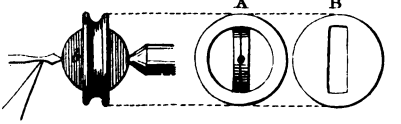

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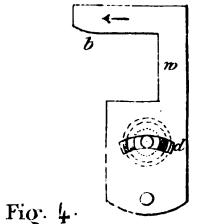

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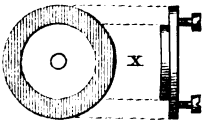

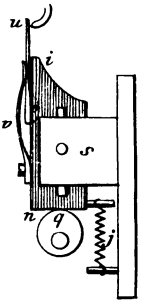

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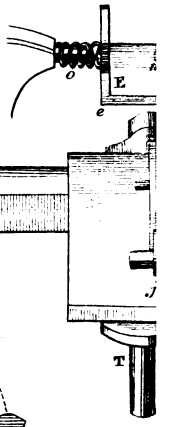

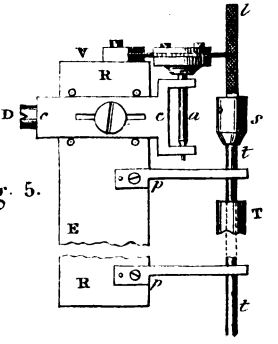

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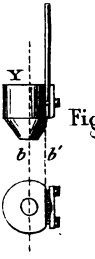

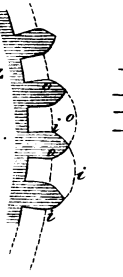

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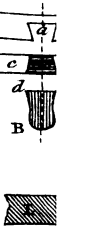

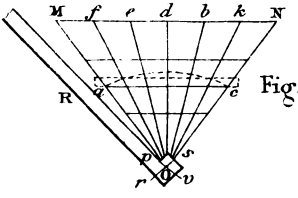

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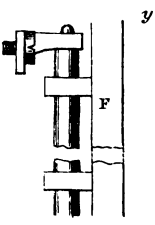

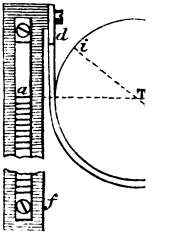

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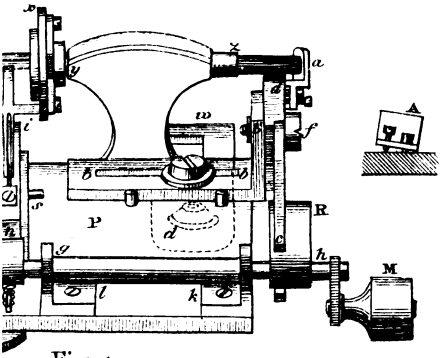

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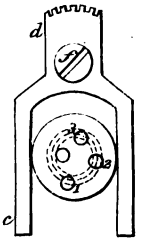

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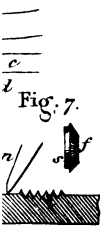

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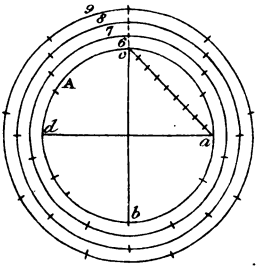

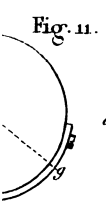

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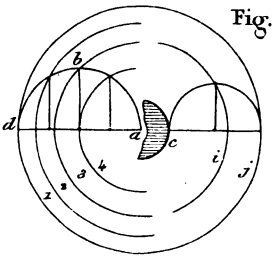

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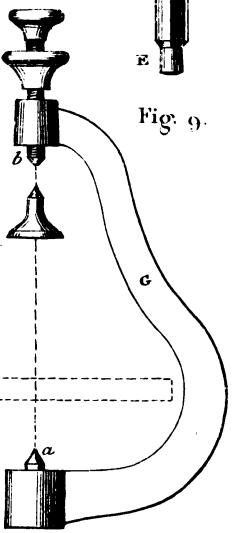

Fig. 9.

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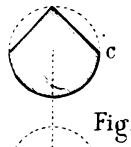

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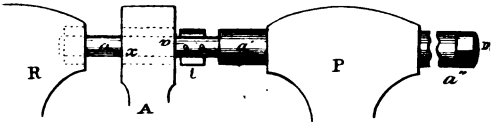

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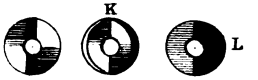

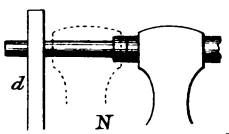

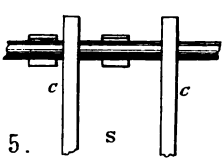

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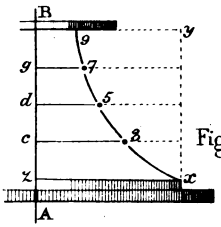

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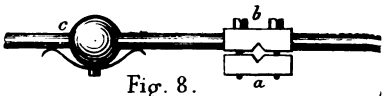

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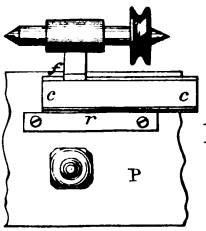

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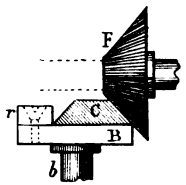

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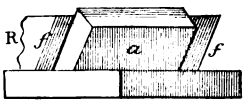

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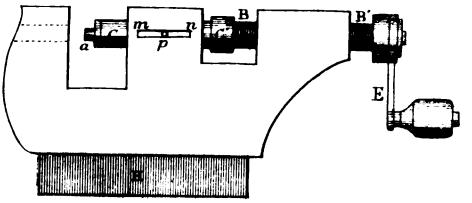

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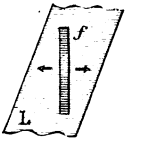

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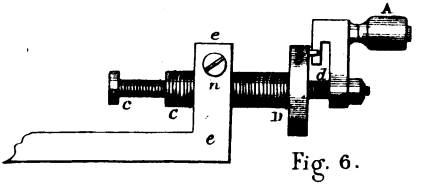

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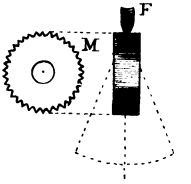


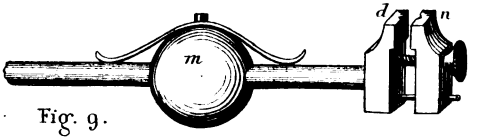
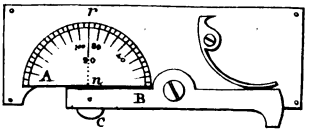
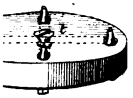


Fig. 9.

Fig. 13.

Fig. 14.





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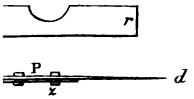

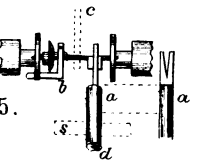

Fig. 15.

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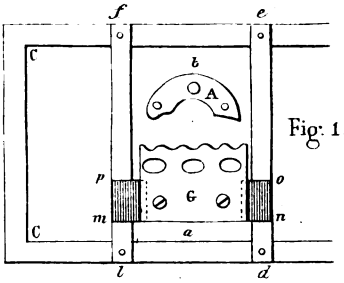

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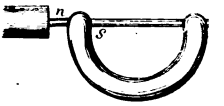

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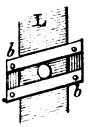

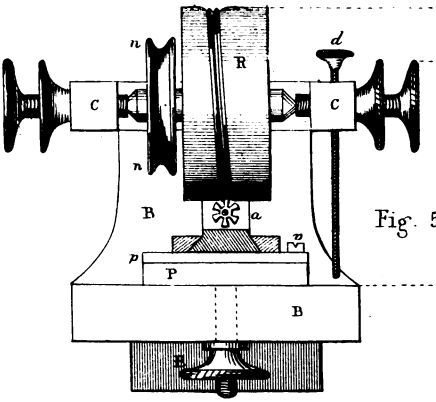

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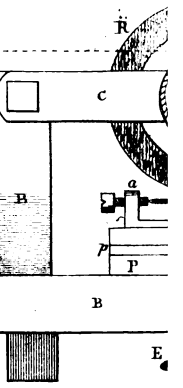

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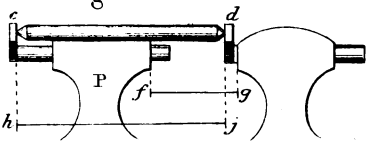

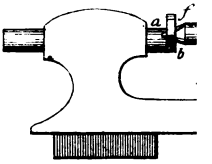

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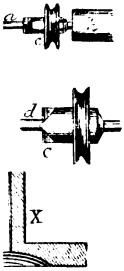

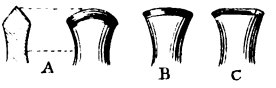

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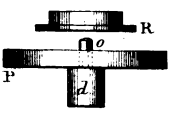

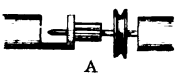

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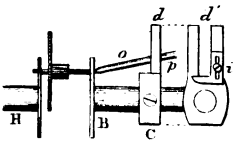

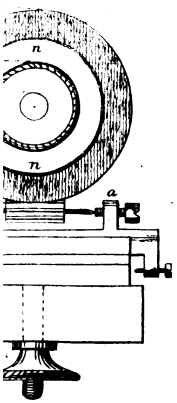

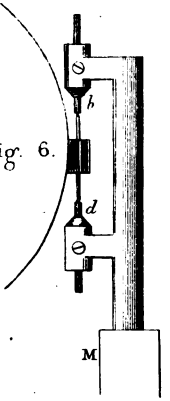

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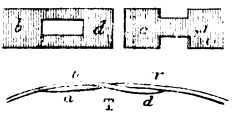

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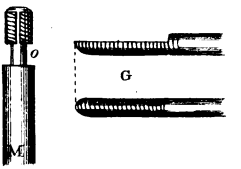

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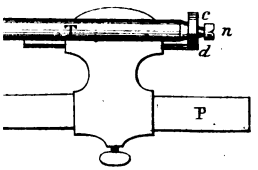

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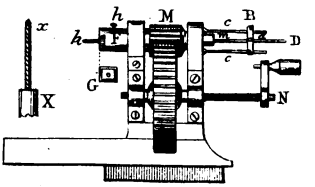

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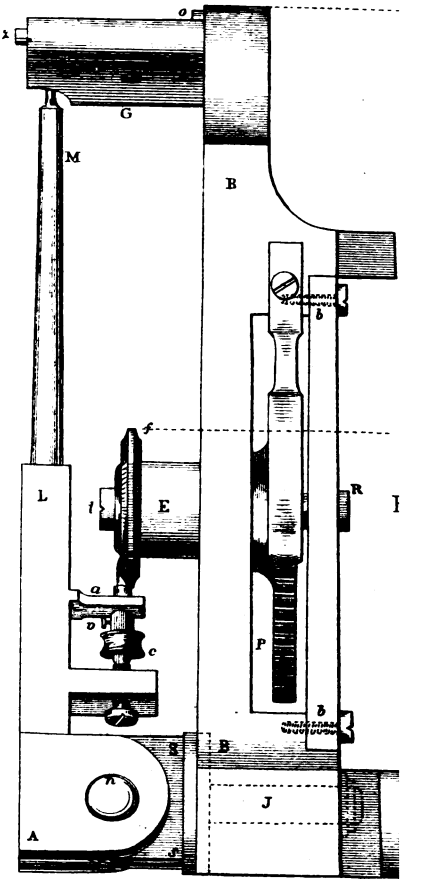

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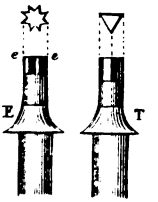

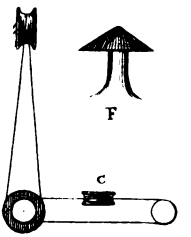

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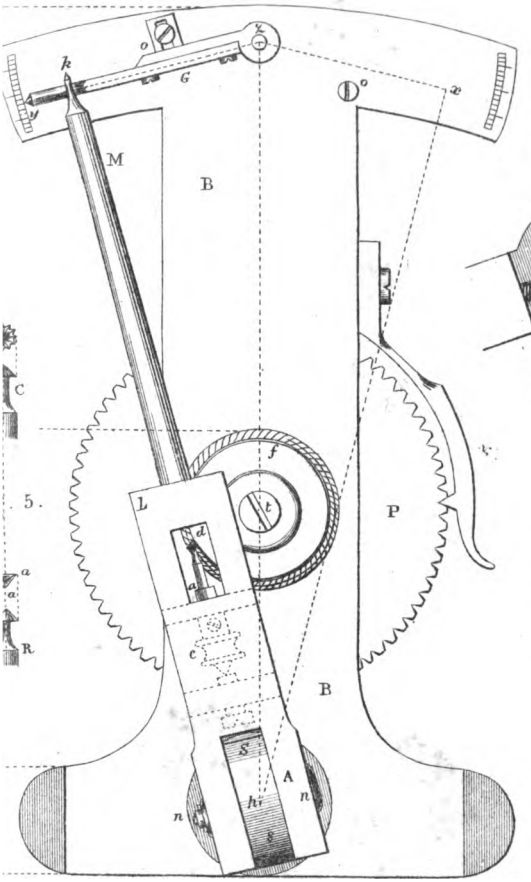

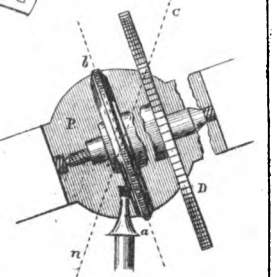

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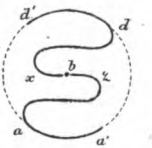

Fig. 7.

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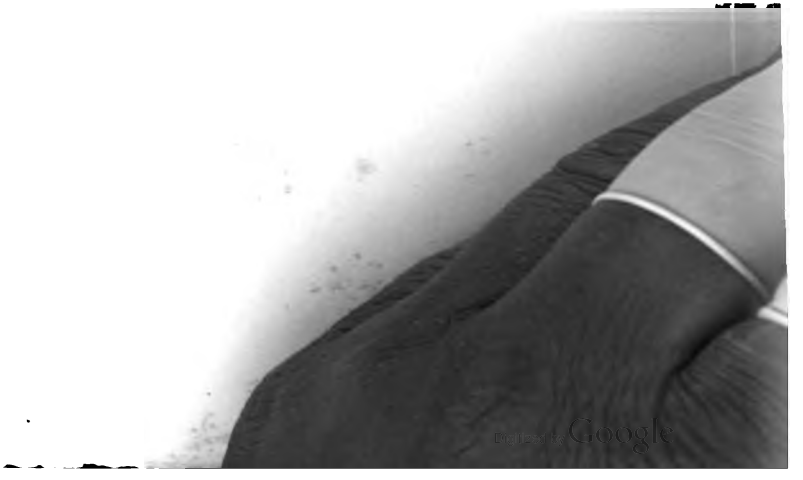
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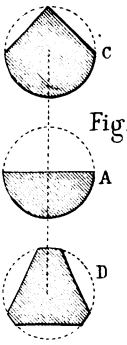

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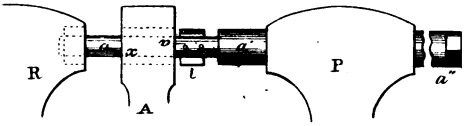

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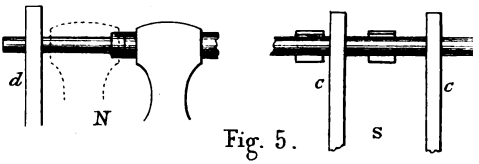

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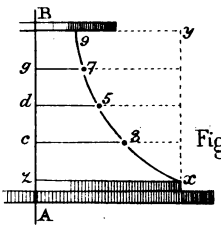

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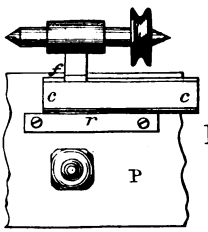

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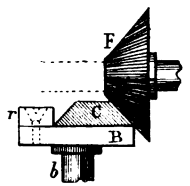

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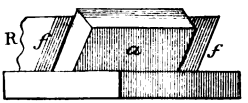

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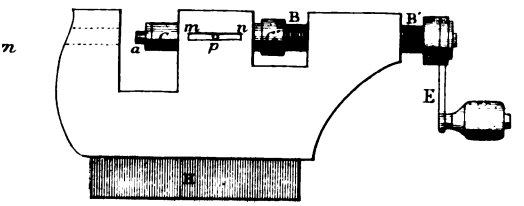

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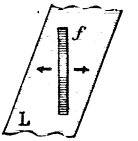

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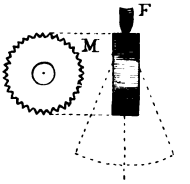

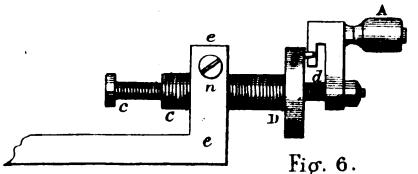

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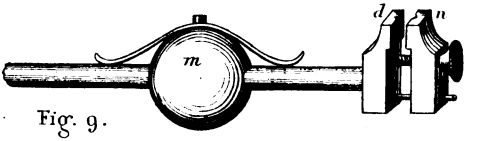
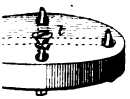


Fig. 9.

Fig. 13.

Fig. 14.



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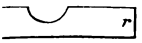

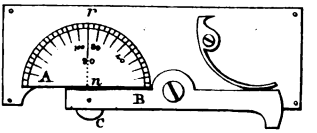

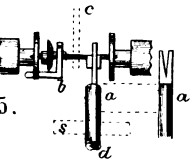

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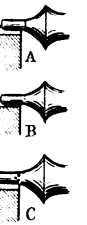

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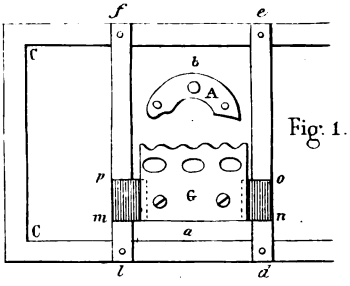

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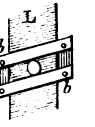

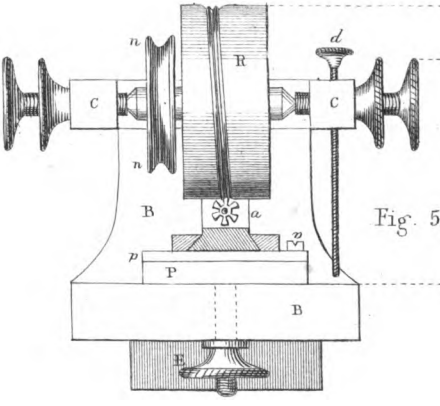

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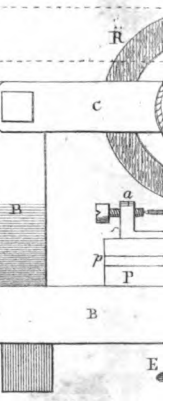

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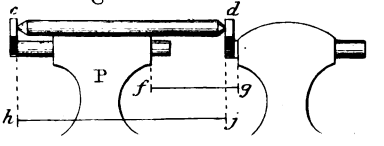

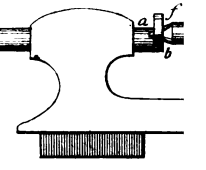

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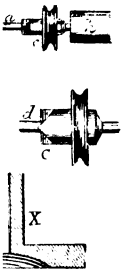

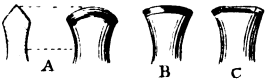

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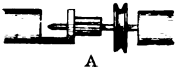

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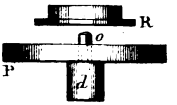

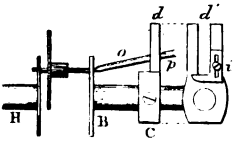

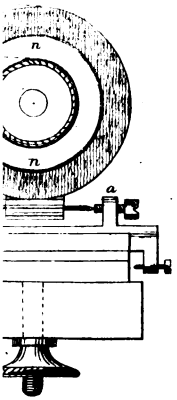

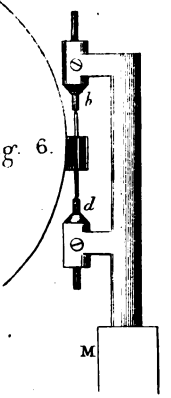

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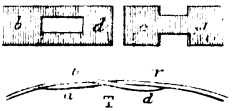

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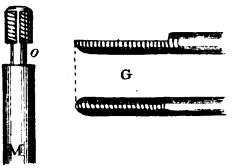

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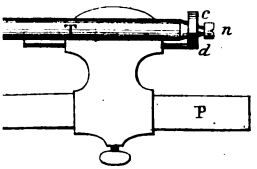

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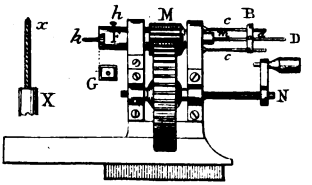

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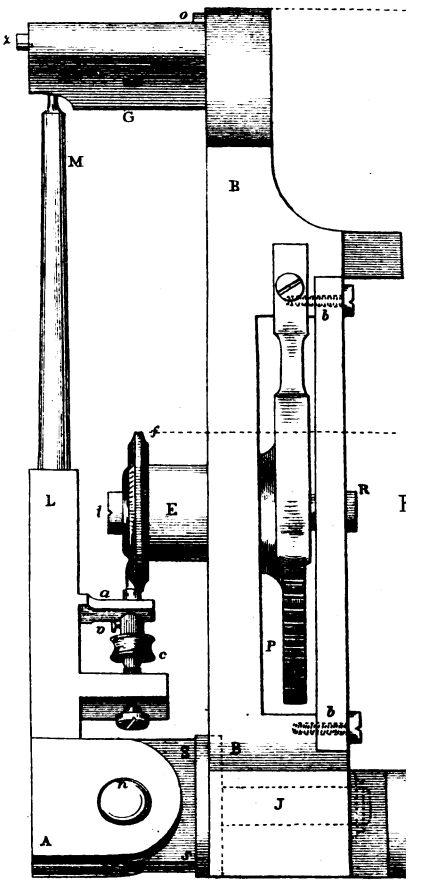

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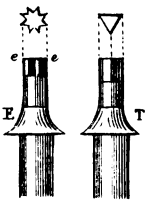

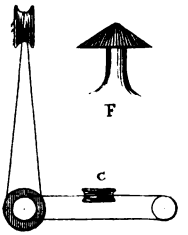

Fig. 4.

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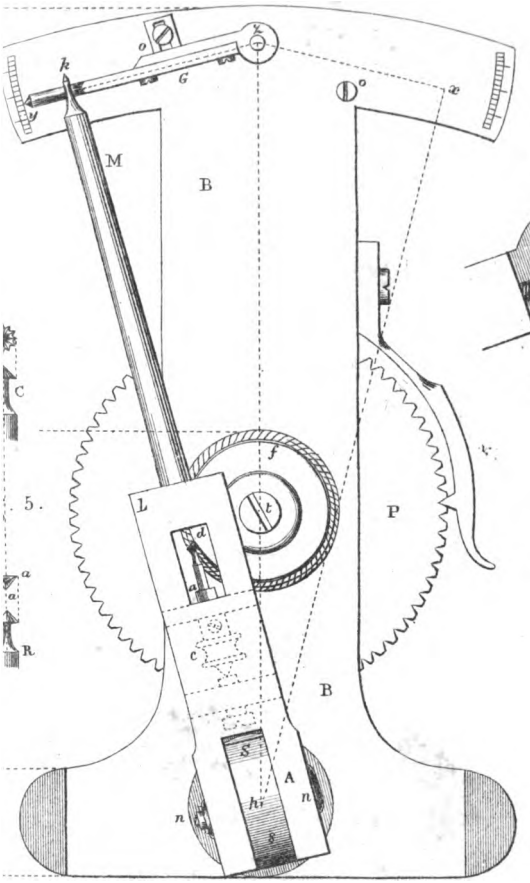

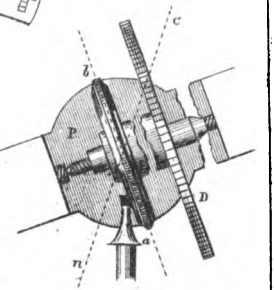

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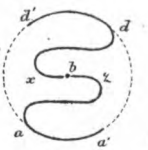

Fig. 7.

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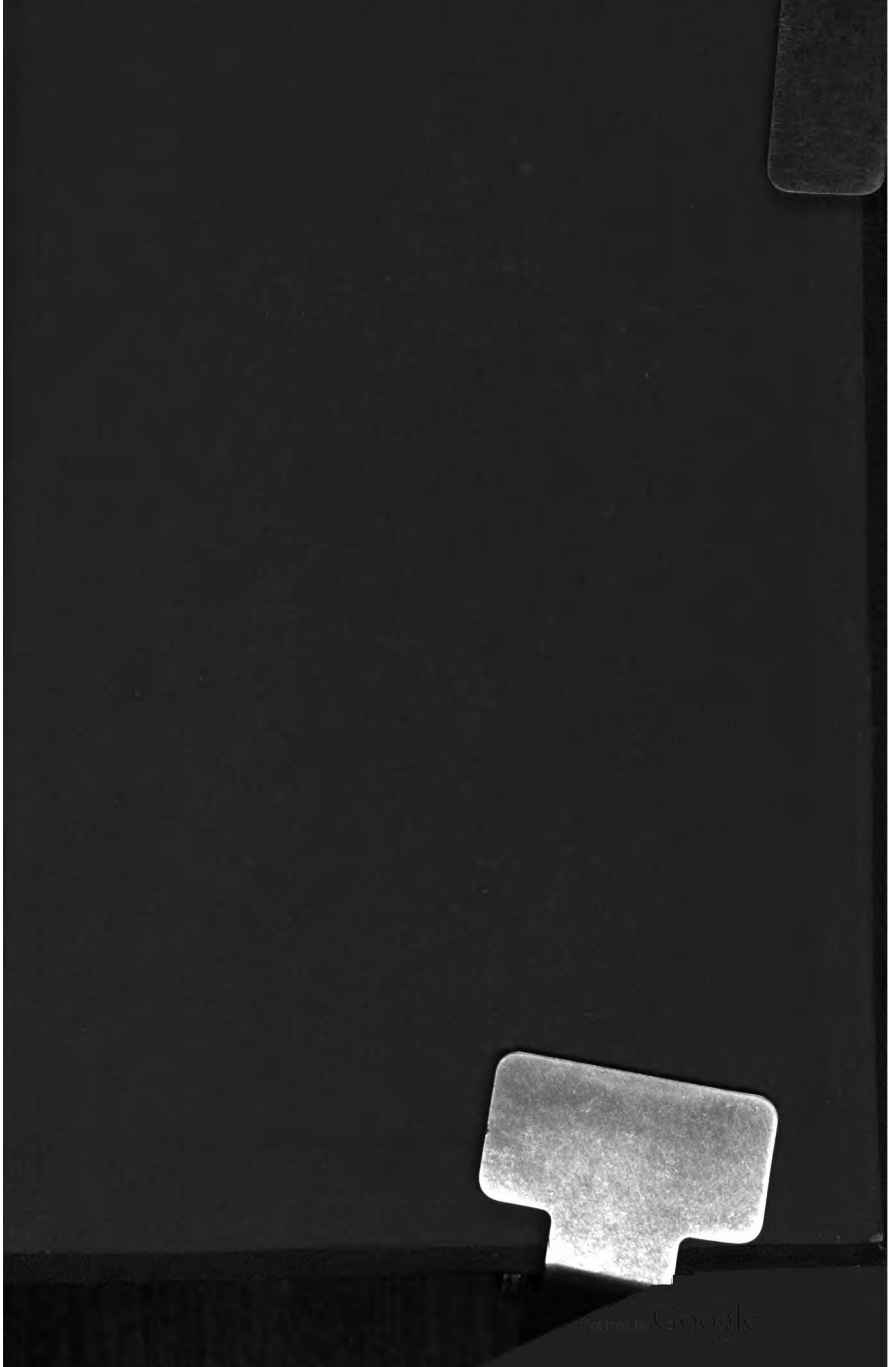
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